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Niagara Falls Meeting of the American Electrochemical Society.

For the third time the American Electrochemical Society is to hold a general meeting at Niagara Falls. The two former meetings, in 1902 and 1903, are unforgotten by those who had the good fortune to attend them. But from all indications it seems certain that this year's meeting will break all previous records, not only in attendance, but in the importance of the professional proceedings. The program, printed on another page, shows a long array of papers on important and interesting subjects. To the special feature of the program—the symposium of papers on the electrometallurgy of iron and steel—we have already called attention at this place in our last issue, though even this part of the program has been further strengthened by lately announced papers by Messrs. Bennie, Catani, Hibbard, and Richards. It is to be sincerely hoped that many practical iron and steel men may participate in the discussion. If practical steel men and electrometallurgists come into closer professional contact for the first time on this occasion, immense good will result for all concerned. That the social functions will be as enjoyable and cordial as ever, goes without saying. And then there are the ever-young charms of the old falls, though it is not out of place here to quote Lord Kelvin, who once said that “the great cataract could never be beautiful until it had ceased to be such an awful and unlovely example of waste.” To reveal the deeper beauty of the Falls, by reducing this unlovely waste, has been the privilege of the electrochemical settlement of Niagara Falls. Two elements have created industrial Niagara Falls—the natural power of the Falls, and, equal if not superior, the power of the men who have made Niagara the principal electrochemical center of the world.

A Dictionary of Chemical and Metallurgical Material.

Within the next two weeks our subscribers and friends will receive a copy of our “Dictionary of Chemical and Metallurgical Material.” By compiling this dictionary the publishers of this journal hope to have done something really useful. The object is not to give a directory of manufacturers, but a dictionary of machinery, appliances and material used in the chemical and metallurgical industries, giving as far as possible, concise technical data on the special features of the different types of machinery, etc., made by different manufacturers. As nothing of this kind has been done before by others, and as this is our own first attempt, this first edition of our dictionary cannot be but far from perfect. But we hope to have made a good and creditable beginning, and we hand the dictionary over to our friends in the fond hope that they may use it and may find it useful, and that where they find us lacking they may favor us with their criticisms, which shall be carefully considered in next year's edition. Then, and then only, can we hope to gradually produce a work that conforms to our intentions.

Metallum Martis et Dea Electra.

Not until the twentieth century arrived, was the conquest considered a possibility. Sir Humphrey Davy played with his large battery in the Royal Institute and isolated sodium and potassium; Elkington actually put the electric current commercially to work, refining copper which contained gold and silver; Hall was the first to use Niagara in harness, and forced 10,000 amperes of unwilling current into a small bathtub of a pot for the isolation of aluminium; Willson discovered electric furnace calcium carbide and founded an industry which is spreading through all the earth. Castner has given us cheaper soap, by electrolyzing the most common salt on earth; Birkenland and Eyde take the air we breathe, and which we do not value because we always get it for nothing, and out of what costs nothing, they make the electric arc bring forth nitric acid, which as nitrates makes crops grow and will keep the human race from prospective starvation; Betts refines lead; Wohlwill refines gold; Moebius refines silver; Gibbs produces chlorates for our matches; Acheson, graphite for our electric apparatus, not to speak of pencils and lubricants; also carborundum to grind and cut with; etc., etc., etc. And thus the electric current decomposes, isolates, compresses, combines, transforms, transmits, refines, corrodes, melts, vaporizes—in other words, has become the chemists' and metallurgists' most powerful and successful agent for solving all the knotty problems of chemistry and metallurgy, for doing what was before impossible.

And above all this turmoil of a century of endeavor, grand, serene, unaffected, "Metallum Martis" kept his majestic way. What had sparks from a cat's back, current from a battery, "juice" from a dynamo, the incandescence of resistance furnaces, the fervent heat of the electric arc, to do with the colossal industry of iron and steel, the metals made by millions of tons on the grandest scale known to metallurgy? Some poor enthusiasts spent their all, and other people's all, finding out the apparent certainty of the impossibility of the "electro-metallurgy of iron and steel." And now, A. D. 1909, *mirabile dictu*, a national society, with international affiliations, devotes one day of its annual meeting to a "symposium on the electro-metallurgy of iron and steel." *The goddess Electra has conquered Mars.*

The Exhaustion of America's Iron Ores.

The visitor to the pleasing city of Sault Ste. Marie, Mich., during the month of May, will be impressed with two things. The first is the bracing and invigorating atmosphere and the second is the endless procession of monster vessels with red-stained hatches that is apparently taking place in the actual streets. Then if the visitor be of an imaginative turn of mind, he can hardly fail to be impressed with this concrete evidence of the importance of the metal iron in this age of metals and will speculate on the future possible exhaustion of this country, for the ships are so large and their presence so recurrent. The seeing of so many thousands of actual tons of iron ore pass before his eyes in so short an interval of time is a practical expression of the rate at which iron ore is being dug out of the ground. This phase of modern life is perplexing. How long can we skim the cream of this rich country? When will we be

forced to take up the skim milk? The stupendous amount of our annual production of mineral wealth is pleasing to the present statistician. But are we using nature's heritage wisely? The discussion of this question has been widespread and general. The conservation of our natural resources and the utilization of them without any useless waste is the only proper course for any nation that wishes to have its national life endure.

* * *

Mr. C. Willard Hayes, chief geologist of the United States Geological Survey, has prepared an inventory of the iron ore of this country in his recent report to the "Conservation Commission." Although it is confessedly in the nature of an estimate, yet as the estimate of a trained observer in the employ of the Federal Government to whom private corporations are willing to give information, it is interesting and illuminating. Mr. Hayes classifies iron ore as available and non-available. The second class has the possibility of future commercial use. He also classifies ore according to its geological formation. In this way it is possible to inventory the reserves and probable future additions to reserves reasoning on the analogy of such additions in the past. The production and consumption of iron and steel has grown at a much more rapid rate than the population. This great increase is due to the diversification of industry and the increasing uses and needs for iron and steel in our modern complex civilized life. In railroad engineering, electrical engineering, and structural engineering, steel is a necessity. As the rate of increase increases many predictions have been made as to the date of exhaustion of commercially available ores.

* * *

Many people have speculated about the question, which, of course, is of vital importance to a country interested so largely in manufacturing and transportation. The production of iron ore has grown by saltations in the past four decades. From 1870 to 1879, inclusive, it was 44,000,000 long tons. The next decade saw it 91,000,000 long tons. Even the hard times from 1893 to 1896 did not hinder the increase greatly, for production totaled in that decade nearly 164,000,000 long tons. In the last 10 years production has reached the enormous sum amount of 392,000,000 long tons. The fact that the deposits of high-grade ore in the principal districts were pretty well known in 1901 and in large measure controlled by several large companies, was made the central conception by a master mind of finance. The circumstance that practically monopolistic control of the natural resources could be attained by the consolidation of several large companies led to the formation of one gigantic corporation that dominates the steel interests in this country. This act has been but the logical conclusion of a series of industrial evolutionary processes, the successive integrations of the small homogeneous entities into one large heterogeneous entity. And it showed that the principles of evolution enunciated by Herbert Spencer hold good in business economics as well as in biology. This consolidation has taken place also by the reason of the large units that are now used. The trainloads, the ore-carrying vessels, the blast furnaces, the steel plants all are measured in terms of hundreds of tons. And the capital to finance such operation is likewise measured in large units, millions of dollars. The simplicity attained through this is one reason for the success of what otherwise might be

failure because of unwieldiness. But more important in the consolidation was the unification of ownership of the ore properties.

* * *

The present outlook for the rapid exhaustion of the known ore fields is much different from that disclosed in the discussion of eight years ago. In the first place the extent of the high-grade ore lands has been increased by prospecting, especially to the extreme west of Mesabi. With the modern methods of prospecting by drilling and of mining by the "caving" system and the application of modern hoisting engines and the transmission of power by the electric current, it is possible to mine ore much deeper and to open up deposits whose character was unfavorable to working by the older appliances and methods. Improvements in the blast-furnace practice and in the refining of steel by the open-hearth process have widened in the past the chemical specifications for ore. This has the effect of increasing the amount of commercial ore by making non-available ore available. Recently the electric furnace has given promise of producing cheaply from semi-refined hot liquid steel, steel of highly excellent physical properties. Looking into the future a bit we see that the electric furnaces have increased the ore reserves—to use a figure of speech—because of the increased service and duty that a ton of steel refined electrically will give as against the service and duty of steel of the present grade. To epitomize, it can be said that the commercial gain may be expressed by the tensile strength of the new steel divided by the tensile strength of ordinary grades, multiplied by the present cost of production, plus the cost of electric refining. This is but a roughly accurate mathematical expression for the purposes of illustration.

* * *

The question of whether an iron ore is an iron ore or is not an iron ore—to resort to a taurian expression—is largely one of commercial availability. If an iron mine can be opened up, its ore transported to a locality where a blast furnace can be built and coal or coke transported to it, and the resulting pig iron be sold at a profit or turned into steel at a profit, its ore can be said to be commercially available. As Mr. Hayes puts it, "the interaction of various factors is the best criterion of availability." The principal iron ore district at present measured in terms of pig iron is the Lake Superior district. Of this the Mesabi range is the chief tonnage producer. Incidentally, it might be remarked that Mesabi as late as 1898 produced a relatively small amount of ore, and its ores were not then classed as commercially available. Their extremely soft nature made their treatment in the blast furnace extremely difficult. Accordingly, reasoning from this past history, it must be expected that in the future the same process of making ores once regarded as valueless will be recurrent. Mr. Hayes from private sources places the ore of present grade to be mined in the Lake Superior iron regions at three and one-half billion tons. Practical iron men consider this rather high. Possibly two billion tons is a fairer figure.

* * *

The most significant remark in Mr. Hayes' entire paper is that the average percentage of metallic iron in the iron formation, excluding the beds now considered ore, exceeds 37 per cent. As many countries, for instance Germany, use ore running less than 32 per cent iron to some extent, it is safe to say

that the use of these hard silicious ores is bound to increase. The comparison of this ore with the ore used abroad is not altogether a fair one, for in the low-grade foreign ores the lime and silica are present in partly fluxing proportions. But in fact considerable hard taconite ore or ore of this general class but running higher in iron (about 45 per cent) is used because of its physical nature and freedom from phosphorus, when mixed with softer ores high in iron but with phosphorus above the Bessemer limit. The amount of this rock above 37 per cent is practically unlimited and is given as 72,000,000,000 tons. The fact that so much scientific brains with practical and engineering ability is guided in the iron business now by minds of rare financial talent, would point to the utilization of these ores in the not so distant future at or near their place of occurrence, with the working up of their silica and alumina when mixed with lime as a by-product "blast-furnace cement." In that event the coal from the fields of the middle West would be transported to the head of lake navigation in vessels now returning empty and coked in by-product ovens. The ore would be smelted for metallic iron and cement and all products used in the then existent large local centers of consumption. This should take place some time before the middle of the present century.

* * *

Next to the lake district, the most important iron ore region, both from a standpoint of present and future development, centers at Birmingham, Ala., and includes the eastern part of Tennessee. Here large supplies of coal and limestone lie in close proximity to the iron ore. This combination makes the cost of producing pig iron at the Southern furnaces very low, and the past 15 years has seen pig iron sold at times at extremely low figures. Its future as a steel center is not so promising by reason of the fact that steel making does not seem to be possible of being successfully conducted in the hot Southern climate. We should rather look to this district as a producer of pig iron to be used elsewhere in the foundry trade or at Northern steel plants. Third in importance is the district called in the catalog "the Northeastern." These ores in the Adirondack Mountains and Jersey hills are largely titaniferous magnetite. Usually they require magnetic concentration, and, furthermore, improved blast-furnace practice. The fact that they are close to the large centers of pig-iron consumption, such as eastern New York and the New England States, enhances their chance for immediate future exploitation. Lack of mining and transportation has restricted their development. But with the price set upon "ore in ground" enhanced by the large consolidations of the past decade these facilities are being vastly improved.

* * *

In the Western Mountain States, there are many large deposits of hæmatite of metamorphic or igneous origin, but the production of ore from them is confined to one locality in Wyoming and another in Mexico. Their future utilization will be deferred to some distant date. Their extent is more or less unknown and with lack of a large market for pig, of good coke, of railroad facilities, possibilities in this field do not seem promising. The future probable success of the electric ore-furnace will render some available, but at most they will add but a mite as their contribution to the pig-iron supply of this world in our generation. With the removal of the tariff on

iron ore, foreign sources are at once made commercially accessible to the blast furnaces at or near tidewater. Cuba now furnishes two large companies with iron ore and even with the proposed tariff on ore will supply them with more ore in the next five years. Canada, north of the Lakes, has been and is now being prospected for mineral, but its future as an ore producer will be largely in the direction of satisfying demands of home consumption. Iron sulfide deposits are being exploited the world over as sources of the raw material for both the sulfuric acid industry and the blast furnace. But the iron production from this source, though promising to be actually large, will, of course, be small compared to the total production. But here again improved metallurgical treatment with the recovery of by-products has widened the iron-ore supply.

* * *

Considering the question of the future of the iron business and its necessity for enormous tonnage of its raw material, it is quite plain that the latest metallurgical methods when combined with proper business judgment are continually opening up vast and unsuspected sources of iron ore. Each successive advancement in the price of pig iron stimulates this endeavor and tends to keep the price of pig iron from advancing materially. The great law of compensation and correction applies here. It is even doubtful if measured in the logical unit—the wage of the unskilled laborer—whether the price of pig iron has much increased over the days when little value was placed on Mesabi's leases. With the great supplies of capital that can be handled in large units, the production of economic values out of supposedly valueless raw materials is becoming surer and more satisfactory. Considering this tendency and the tendency to operate at the highest metallurgical and industrial efficiency, the utilization and exploitation of iron ores will increase greatly our national wealth. The vast size of this country of "unlimited possibilities" will undoubtedly develop areas now unknown or slightly known into producers of iron ore. Combining all these factors with the significant fact that iron is not destroyed by consumption, but that a high percentage of all iron returns to the market in the form of scrap, leads us to the conclusion that the so-called future "iron famine" is not greatly to be dreaded. Indeed, the Cassandra-like prophecies of the pessimists who pointed out the year 1940 as the apogee of the United States pig-iron production and its decline subsequent to that date, are, to say the least, beside the mark. Any decided rise in price would in 10 years so stimulate prospecting for new sources of ore and metallurgical research for new processes, as to greatly increase the future production. In the "age of aluminium reinforced concrete," the millennium will be seen not so far distant.

A New Era of Fine Steel.

A distinctly new era is being inaugurated in the steel trade—an era of the manufacture of fine steel. As is often the case when a sweeping change occurs in any branch of human affairs, there are many contributory causes which seem all to focus their influence upon one point of time, when really what is mistaken for the focal point is simply a center of diffusion. Some of the influences come to bear earlier and some later, the individual forces not being clearly recognized until the aggregate is seen. When we say there is being inaugurated an era

of the manufacture of fine steel we do not mean that the quality of every ton of steel is necessarily to be greatly improved, nor do we mean to lose sight of the fact that some fine steel has always been made. We know that fine steel was the first steel produced and that the material which is now meant when the term steel is used without any modifying phrase is a later invention, a material which the Germans have been disposed to refuse to call steel at all. What we mean is that the proportion of fine steel to total steel produced is going to increase very rapidly until it constitutes a large percentage instead of an almost negligible percentage.

* * *

There are no statistics of American steel production in which the segregation is on the basis of quality, the segregation being only as to process of manufacture. From these statistics, however, one can obtain a rough approximation of the proportion of fine steel produced. The earliest year in steel statistics is 1867, the record for which is 2679 gross tons of Bessemer steel ingots and castings, no open-hearth steel, and 16,964 tons made by the crucible and other processes. Then we have the following decennial statistics, with the figures for the past three years added:

	Bessemer.	Acid.	Open-hearth. Basic.	Crucible.	Miscellaneous. Unclassified.	Total.
1870..	37,500	1,339		29,911		68,750
1880..	1,074,262	100,851		64,664	7,558	1,247,335
1890..	3,688,871	513,232		71,175	3,793	4,277,071
1900..	6,684,770	853,044	2,545,091	100,562	4,862	10,188,329
1906..	12,275,830	1,321,653	9,658,760	127,513	14,380	23,398,136
1907..	11,667,549	1,270,421	10,279,315	131,234	14,075	23,362,594
1908..	6,116,755	696,304	7,084,568			

*Not yet reported.

All the crucible steel and the greater part of the acid open-hearth steel may be regarded as fine steel. A large portion of the Bessemer product was hard steel, but is not to be considered fine steel in the sense in which that somewhat broad term is applied here.

* * *

In 1880, when 100,000 or 150,000 tons of fine steel was produced, the proportion it constituted of the total steel output, in the neighborhood of 10 per cent, is not significant, for at that time there was a large tonnage of wrought iron being produced (1,641,880 gross tons of rolled iron in 1880) which material was afterward replaced very largely by mild steel, an incident which is not of material import in this connection. It is a perfectly legitimate citation, however, that the total steel production increased by 115 per cent from 1900 to 1907, while the production of crucible steel increased only 30 per cent, and the production of acid open-hearth steel only 42 per cent. There has been a rapid increase in production of high-speed and other very fine steels, but the tonnage, as compared with that of mild steel, naturally remains negligible. It remains, then, that up to date the great mass of the so-called "steel" produced—more than 95 per cent of the total—has been simply mild steel or steel which is hardened by the presence of a moderate amount, less than 1 per cent, of carbon.

* * *

This alignment is destined to undergo a striking change, through the combination at this time of a number of influences. These influences are partly commercial and partly technical. The commercial influences make it particularly desirable that fine steel should be adopted for certain purposes, while the technical influences comprise the furnishing of means whereby

the steel can be produced advantageously. If it costs a certain price per ton to improve the quality of steel, then the desirability of doing so will increase as the cost of producing a ton of ordinary steel increases, the cost per ton of improving remaining stationary. Of the finer steel a smaller quantity is required to do a given work, and the higher the cost of the fundamental material the greater is the saving from this fact. In the middle nineties Lake Superior ore was "as cheap as dirt." Leases at 25 cents a ton on very good ore deposits went begging. In Alabama the outcrops of fairly good ore veins were being used, with a relatively low cost for mining. In a dozen years the fundamental conditions have changed, the cost of mining being greatly increased while a sufficient proportion of the original deposits has been mined to make the question of ultimate exhaustion one of academic interest at least, since with the 1907 rate of mining the known ore reserves in the Lake Superior region would be exhausted in less than half a century. Thus the value of ore has increased along with the cost of mining. At this point human nature has introduced an interesting factor. A comparatively high present value was set upon Lake Superior ore in the ground a few years ago. As present value is a function of interest charges, increasing heavily as the time of realization is deferred, the steel trade has favored the alignment of manufacture and use which would make for the earliest exhaustion. Its desire has been for "tonnage," leaving to the demand of the consumer rather than to its own initiative any movement toward finer steel whereby tonnage would be reduced while the same service would be furnished. There has also been a material enhancement in the value of coking coal in the ground and in the cost of producing coke from it. Thus the proposition of the cost of raw material to total cost of producing a ton of steel has greatly increased. Thereby the desirability of improving the quality of the steel has been likewise increased.

* * *

When steel wears out in the use to which it is put the increased price which can be paid for better steel is a matter of interest and sinking fund charges. If the life of the steel be indefinitely long the interest charge is everything, the cost of replacement being negligible, and the cheapest steel is adopted. If the life be indefinitely small, interest charge is negligible and the cost of replacement is everything. It pays to buy steel at double the price if it will last twice as long. Between these limits it is a matter of computation. At 6 per cent interest, the interest charge and the sinking fund charge against material which must be replaced every 11 or 12 years are equal. For each period of life a computation can be made as to how much more one can afford to pay for steel if thereby the life is increased by so much. Now if the conditions of service are so changed that a given piece of steel must do much more work each year of its life, the period of life is shortened, the sinking fund charge is increased and there is more room for saving by decreasing it through using steel which will last longer at the expense of a greater interest charge.

* * *

This change of conditions has been taking place steadily with the railroads. In 1890 the total ton-mileage of freight moved per mile of track was 380,000; in 1900 it had increased to 547,000, while in 1907 it increased again to 719,000. These

figures understate the case in all probability, for the proportion of siding and yard track has probably increased, while the density of traffic on certain much-used stretches has probably increased more than has the average movement. On account of greater speeds and more concentrated load, the duty upon a given rail has been greatly increased, proportionate to freight movement. These influences shorten the life of a rail and greatly increase the sinking fund charge for replacement, permitting a saving by increasing the interest charge through using a more costly rail, but reducing by a greater amount the sinking fund charge. The extreme case is found in some yards or on some main-line curves where the life of an ordinary rail is measured by days rather than by months or years. At such points steel costing a very high price per ton can be employed.

* * *

With a given tensile strength there is a length of suspended cable which will break of its own weight. Just under that limit the cross-section required to support a load in addition is very large, and a high premium per ton of steel can be paid for load-carrying capacity. Those regions are being approached in an increasing number of cases as mining operations are being carried deeper and deeper. Several years ago skyscrapers reached a height which made the employment of better steel, particularly for the lower members, appeal very strongly to the engineering profession, on account of the great increase in the proportion of load to be carried which was furnished by the steel itself. The appeal in turn of the engineers to the steel mills did not meet with much response, however, since, as already suggested, the spirit actuating the manufacturing trade was the desire for tonnage.

* * *

The influences determining the selection of steel of one grade or another in the cases just referred to lie within the operation itself. In the case of automobiles, air ships and flying machines there are extraneous influences of the greatest importance, which present necessities of reducing weight quite superior to the question of first cost. These influences are not new; they have been growing steadily. From late in 1904 until October, 1907, the capacity of steel mills was strained and deliveries were so delayed that buyers as a rule were glad to get regular material. There was little opportunity for them to insist upon special steels, as there was ample demand from one quarter or another for all the ordinary steel which the mills could produce. Since the latter part of 1907 some steel capacity has been idle, and the commercial opportunity is presented for the buyer's changed requirements to be considered. Leisure is afforded for study of the conditions and the incentive has arisen for obtaining orders by applying suction when formerly the orders flowed under the pressure of their own head. The fine steel which is thus about to come into statistical prominence will be partly alloy steel made by former processes and partly fine steel made in electric refining furnaces. It is quite certain, however, that the alloy steel, too, will be made in electric furnaces. It will be largely a growth from beginnings already made. For years there has been some use of cast manganese steel in frog and crossing work; as the use of steel of similar durability extends to yard track and main line curves the tonnage will be rapidly augmented, and so through many lines of use where pioneer work has already been done.

Program of the Niagara Falls Meeting of the American Electrochemical Society.

The program of the fifteenth general meeting of the American Electrochemical Society, to be held at Niagara Falls, Canada, May 6, 7 and 8, is as follows:

All the sessions of the society will be held in the convention room at the Clifton Hotel, Niagara Falls, Canada.

The whole session of **Thursday**, May 6, will be devoted to a symposium on the electrometallurgy of iron and steel. The following papers will be presented during the morning:

Robert Turnbull, resident American engineer for Dr. P. L. T. Héroult: "The Héroult electric steel furnace."

Paul Girod, director, Société Anon. Electrometallurgique Procédés Girod, Ugine, Savoie, France: "The new Girod electric steel works."

Dr. A. Kjellin, electrometallurgical engineer, Metallurgiska Patent Altiefbolag, Stockholm, Sweden: "Developments of the induction and combination furnaces."

Cav. Ernesto Stassano, director, Forni Ellettrici Stassano, Turin, Italy: "Electrometallurgy of iron and steel."

Remo Catani, electrometallurgist of the Société Elba, Portoferraro, Elba, Italy: "Large electric steel furnaces in the iron and steel industry."

Charles A. Keller, general manager, Société des Etablissements Keller-Leleux, Livet, Isère, France: "A contribution to the study of electric furnaces for the electrothermic treatment of iron and steel."

Gustave Gin, electrometallurgist, Société Procédés Gin, Paris: "A contribution to the electrometallurgy of iron and steel."

Henry D. Hibbard, consulting engineer, Plainfield, N. J.: "The present value of electric steel."

F. A. J. FitzGerald, consulting electrometallurgist, FitzGerald & Bennie, Niagara Falls: "The application of the Lash process to the electric furnace."

P. McN. Bennie, consulting metallurgist, FitzGerald & Bennie, Niagara Falls: "Electric-furnace pig iron in California."

Joseph W. Richards, professor of metallurgy, Lehigh University: "The electric-furnace reduction of iron ore."

In the afternoon there will be a general discussion of the above papers, and if time is left, the following papers will also be presented:

C. A. Hansen: "Furnace electrode losses."

Carl Hering: "The working limit in electrical furnaces due to the 'pinch' phenomenon."

E. F. Northrup: "A new type of ammeter for the accurate measurement of alternating currents above 1000 amp."

Charles E. Foster: "A new radiation pyrometer."

E. F. Northrup: "The automatic registration of temperatures."

In the evening, at 8 o'clock, Dr. E. G. Acheson, as the retiring president of the society, will present his presidential address, the subject of which will be "The electrochemist and the conservation of our national resources."

On **Friday** the annual business meeting of the society will be held in the morning, which will be followed by the presentation of the following papers:

E. F. Kern: "Addition agents in electrolytic plating plants."

S. A. Tucker and E. G. Thomssen: "Electrolytic precipitation of lead and zinc as affected by the addition of certain organic compounds."

H. E. Patten and W. R. Mott: "Electrodeposition of some metals from acetone solutions."

S. A. Tucker and E. G. Thomssen: "The deposition of aluminium from aqueous solutions, using rotating cathodes."

W. J. McCaughey: "The electrodeposition of platinum."

John A. Yunk: "Electrolytic production of white lead and colors."

G. A. Hulett: "Thermodynamics of the Weston standard cell."

H. E. Patton and W. J. McCaughey: "The electrolytic reduction of nitric acid—II."

For **Saturday** morning the following papers are on the program:

A. H. Patterson: "The probable electrical nature of chemical energy."

L. H. Baekeland: "Bakelite and its electrical and electrochemical applications."

J. W. Turrentine: "A graphite cathode dish."

S. A. Tucker, W. A. Alexander and H. K. Hudson: "Relative efficiency of the arc and resistance furnace for the manufacture of calcium carbide."

C. I. Zimmerman: "Some physical properties of silicon."

C. F. Burgess: "Magnetic tests of some iron alloys."

O. P. Watts and E. R. Suhm: "Further experiments with calcium alloys as reducing agents."

F. K. Cameron: "Electrochemical methods of soil analysis."

J. W. Turrentine: "A modified oxy-hydrogen gas coulometer."

L. S. Palmer and R. C. Palmer: "Rapid electrochemical analysis—a comparison of several methods."

W. H. Walker: "An answer to Professor Ganz's questions on the corrosion of iron."

* * *

The program of social functions, excursions, etc., is as follows:

On **Thursday** evening after Dr. Acheson's presidential address a smoker will be held at the Clifton Hotel.

On **Friday** afternoon visits will be paid to the different power companies on the Canadian side.

On the evening of **Friday**, a banquet will be held at the Clifton Hotel.

On **Saturday** afternoon, visits will be paid to two of the largest electrochemical plants at Niagara. First, to the works of the Development and Funding Company, where the Townsend process for electrolysis of sodium chloride is in operation. This invitation is extended with the following qualifications: "All persons who are associated with similar or allied industries in the manufacture of caustic alkali and bleach are requested to confer with the manager, Mr. A. H. Hooker, or Dr. L. H. Baekeland, and will be admitted under the condition that they extend a reciprocal courtesy to the management of the Development and Funding Company."

The second plant to be visited is the works of the International Acheson Graphite Company. After that the power house of the Niagara Falls Power Company and the power house of the Niagara Falls Hydraulic Power and Manufacturing Company will be visited.

On the evening of **Saturday** the Niagara Club will tender the society and its guests an "Open House" at the clubhouse, corner of Buffalo Avenue and First Street, Niagara Falls, N. Y.

* * *

The following program has been arranged for the entertainment of ladies:

On **Thursday** afternoon, Mrs. Edward Goodrich Acheson will entertain the ladies of the convention at a garden party at her home on Lundy's Lane, from 4 to 6 o'clock. Conveyances will be provided.

On **Friday** morning at 11 o'clock the ladies' committee has arranged for an automobile drive to Fort Niagara on Lake Ontario. After a picnic luncheon the return journey will be made by Niagara-on-the-Lake.

* * *

Mr. J. L. Harper is chairman and Mr. L. E. Saunders is secretary of the general Niagara Falls committee; Mr. F. J. Tone is the chairman of the executive committee. Chairmen of the other committees are: Mr. E. C. Speiden, entertainment committee; Mr. O. E. Dunlap, press committee; Mr. P. P. Barton, excursion committee; Mr. G. E. Cox, reception committee, and Mrs. P. P. Barton, ladies' committee.

American Institute of Chemical Engineers.

The semi-annual meeting of the Institute will be held on June 24 and 25 in New York City. Dr. J. C. Olsen, Polytechnic Institute, Brooklyn, is the secretary.

Iron and Steel Institute.

The annual meeting of the Iron and Steel Institute (of Great Britain) will be held on May 13 and 14, in London.

The Bessemer gold medal, 1909, will be presented to M. A. Pourcel, of Paris.

The list of papers to be presented is as follows:

"The Production of Iron Sheet and Tubes in One Operation," by S. Cowper-Cowles.

"The Preservation of Iron and Steel," by Dr. A. S. Cushman.

"The Manufacture of Peat Fuel," by Dr. M. Ekenberg.

"The Chemical Physics Involved in the Decarburization of Iron-Carbon Alloys," by W. H. Hatfield.

"The Relation of the Solubility of Iron and Steel in Sulphuric Acid to Its Heat Treatment," by Prof. E. Heyn and O. Bauer.

"High-Tension Steels," by P. Longmuir.

"The Bristol Recording Pyrometer," by P. Longmuir and T. Swinden.

"A Heat-Treatment Study of Bessemer Steels," by Prof. A. McWilliam and E. J. Barnes.

"The Value of Physical Tests in the Selection and Testing of Protective Coatings for Iron and Steel," by J. Cruikshank Smith.

"Further Experiments on the Ageing of Mild Steel," by C. E. Stromeyer.

"A Comparison of the Methods of Determining the Hardness of Iron and Steel," by Prof. T. Turner.

"The Rusting of Iron, and Modern Methods for Its Prevention," by Prof. W. H. Walker.

A supplement to the report on the Determination of Carbon and Phosphorus in Steel, presented by the special committee appointed in 1901, will be submitted by Mr. A. A. Blair.

The autumn meeting is to be held in London on Sept. 28, 29 and 30.

Electric Iron Ore Reduction in Sweden.

In our March issue we reported that Dr. Haanel has returned to this country from his investigation of the electric iron-reduction furnace of the Elektrometall-Aktiebolaget Ludvika, at Domnarvjet, Sweden. While the full account of the tests will be contained in the official report to be made by Dr. Haanel to the Canadian Government, we find the following notes by Professor Neumann, who has seen the furnace, in *Stahl und Eisen* for Feb. 24:

It is a 1000-hp, three-phase furnace with carbon electrodes and with a shaft, similar in design to a blast furnace. The height of the shaft is 5.5 m (18 ft.). "Here is a possibility of utilizing the reducing nature of the carbon monoxide as in the blast furnace, the furnace gases are employed together with other gases." The consumption of coke per 1000 kg of pig iron produced has been reduced to 275 kg. Though the ore and coke contained sulphur (0.55 per cent), the sulphur content in the pig iron was very low, 0.005 per cent. The slag contained only 0.35 per cent iron.

The Iron and Steel Market.

There has been a general improvement in the tonnage of steel business placed. The buying trade is still proceeding with the utmost conservatism and placing orders only for early delivery. It is obvious that all material bought and delivered is passing promptly into ultimate consumption. Stocks are ex-

tremely low all along the line from the steel mill to the point of final consumption. The country is really "short" of steel products, as it is transacting its business with stocks far below the quantity normally involved in carrying on activities of the present volume. A movement to augment stocks would require a large increase in production, but the probability is that the present conservative policy will continue, and that production will do no more than increase gradually and that only after the summer dullness has come and gone.

The present rate of production is really quite satisfactory. Thus far this year pig iron has been produced at a rate exceeding 21,500,000 tons a year, against a rate of 14,000,000 tons in the first half of last year and 18,000,000 in the second half, while the greatest calendar year's output was 25,781,361 tons, in 1907. Until 1905 the best calendar year's production was only 18,009,252 tons, in 1903.

There has been some accumulation of pig iron stocks, but the stocks, above a fair normal, do not exceed about a fortnight's production and have required many months in the accumulation. They are held chiefly by merchant furnaces unwilling to sell at the present price level.

Open market prices on bars, plates and shapes have yielded about a dollar a ton since last report. The recession was due in large part to the inauguration of quite aggressive competition between the United States Steel Corporation and the Jones & Laughlin Steel Company, growing out of the former interest booking a plate order from the American Car & Foundry Company at an unexpectedly low price, the Jones & Laughlin Steel Company, with another independent steel producer, having hitherto supplied this consumer.

Shading in wire products became more pronounced about the middle of April, a concession of 10 cents a keg being made on nails in the case of particularly desirable business, while a concession of 5 cents a hundred on wire nails, plain wire and barb wire is quite general. No formal reduction in wire products has been made on this movement, the present nominal market being that established by the \$2 a ton reduction of June 9, 1908. As there was an advance September 3, 1907, of \$1 a ton, the present nominal market is only \$1 a ton below the regular market ruling the first eight months of 1907. It is recognized that when a general reduction in wire products is made it will necessarily be a heavy one, and it has been the desire to postpone the readjustment until the spring business is well over. A general reduction may now be made at any time, and is likely to be \$4 to \$6 a ton from the present nominal basis, \$1.95 for nails and \$1.80 for plain wire.

Pig Iron.

There has been a material change in the complexion of the pig iron market, suggesting the probability that after three months of stagnation and steadily declining values a general, although possibly slight, upturn will occur. In Southern iron there is no question that the turning point has been passed. Through the first three months of the year Southern pig iron declined from \$13 to \$11, Birmingham, with a few forced sales in March at \$10.50 for spot cash. Late in March large inquiry appeared, and in the first three weeks of April sales were made totaling at least 200,000 tons, for prompt and third quarter delivery, with some tonnage running to the end of the year. This business was all on the basis of \$11, Birmingham, and furnaces then began advancing prices for forward delivery. For early delivery a little iron can probably be picked up at \$11, but for third quarter \$11.50 is demanded, while some producers are asking \$12, and even \$12.50 for fourth quarter.

Following this movement there appeared considerably heavier inquiry for Northern iron, including, for foundry iron, the Westinghouse Electric & Manufacturing Company, 10,000 tons; the General Electric Company, 11,000 tons, and the Massillon Iron & Steel Company, 24,000 tons. Most of this iron has been bought. Inquiries for basic iron exceeding 50,000 tons appeared from large steel-casting companies and small steel

works which roll their product. Bessemer iron has been entirely neglected. Prices of pig iron in the Central West declined in the early part of April, and at the close of the month may be quoted for early delivery, May and June, at \$14 for basic and No. 2 foundry and \$14.75 for Bessemer, f.o.b. valley furnace, while for third quarter delivery from 25 cents to 50 cents more is asked.

Billets and Sheet Bars.

There has been scarcely any market movement, as consumers are well covered by long-term contracts. Shipments of both billets and sheet bars have increased on such contracts. Pittsburgh prices remain at \$23 for billets and \$25.50 for sheet bars, although it is possible these figures might be shaded slightly on very desirable business. A sale of 500 tons of forging billets is reported at \$26, delivered Chicago, comparable with \$24, delivered, for rolling billets.

Finished Material.

Standard rails have continued in light demand, partly because the railroads do not feel in position to make extensive improvements and partly because there is a more or less general expectation that the standard price of \$28 will be reduced by \$3 or \$4, if not for this season then for 1910. There has been increased competition in light rails and \$22, Pittsburgh or Buffalo, can be done on sections 20 lb. to 45 lb.

Plates have been quiet except for a good movement to pipe mills and steel-car works. The regular market, for fairly desirable orders, is 1.25 cents, Pittsburgh, against the price of 1.30 cents developed in February. On especially attractive business this would be shaded.

Structural material continues to lead in point of activity. On large lots involving definite structural jobs inside prices are made, probably down to 1.10 cents or lower. The openly quoted market is about 1.25 cents, against 1.30 cents, the price developed in February.

There has been a good run of business in steel bars, while specifications against old contracts have been quite satisfactory. The openly quoted market has declined from 1.20 cents to 1.15 cents, at Pittsburgh, and from 1.35 cents to 1.30 cents, at Chicago. Attractive tonnages have been taken down to 1.10 cents, Pittsburgh, in which case it is understood the full freight of 18 cents to Chicago is added.

Sheets and tin plates have remained at prices first developed when the general readjustment was undertaken, ordinary carloads of sheets being 2.25 cents for black and 3.25 cents for galvanized, 28 gage, while on attractive orders 5 cents per 100 lb. less is usually done. Tin plates are \$3.40 per 100-lb. cokes in carload or larger lots. The tin mills are running practically full, this being the busiest season of the year, while about 60 per cent of the sheet capacity is engaged.

CORRESPONDENCE

Cost of Water-power in Norway.

To the Editor of Electrochemical and Metallurgical Industry:

SIR:—I have read with interest several notes and articles in your journal on the cost of water-power. As I have been interested in the utilization of water-power in Norway for the last 18 years I send you the following information about the cost in Norway, which may be of interest to the readers of your journal. There is no doubt that the new Norwegian law on water-power, which is to be worked out, will make it more easy for foreign capital to be invested in enterprise in Norway.

The fjords are safe, very deep, and there are hardly ever any troubles from ice on the western and northern coast. In order to illustrate the cost of water-power, which, of course, differs according to the circumstances, I give you an estimate on the development of a 50,000-hp water-power on the western coast of Norway.

More than 6 cm (1585 gal.) of water per second are available for the whole year, with a difference of level of 880 m (2886 ft.).

The fall is divided into two steps, each of 440 m, one station being situated at the coast, the other station at a distance of 2500 m from the coast.

The estimate* for the development of 50,000 (metric) hp is as follows:

Cost of regulation	crowns 256,000
Tunnel—length, 3,000, meters.....	360,000
Steel pipes, 830 meters length for each fall, each crowns 675,000.....	1,350,000
Foundation for pipes	24,900
Freight and laying of pipes.....	50,000
Two turbine-houses	60,000
Turbines and generators (estimated at 6 crowns per h.p.).....	300,000
Price of water falls, ground, etc.....	900,000

Total crowns 3,300,900 or \$885,000 or about crowns 66 per metric horse-power (about \$18 per horse-power) at the switchboard, including dynamos, and large ground of some 170,000 sq. m (about 1,800,000 sq. ft.), directly at a harbor free from ice and navigable for the largest ships.

BERGIN, NORWAY.

HENRY E. MOHN.

Electric Steel for Rails.

To the Editor of Electrochemical and Metallurgical Industry:

SIR:—With reference to your recent articles commenting upon "the adoption of the Héroult furnace by the United States Steel Corporation," we feel sure that you are always ready to give credit where credit is due and therefore draw your attention to the fact that the Steel Corporation is not "the pioneer of electric refining of steel for large tonnage products." The corporation is only following the lead of the Roehlingsche Eisen- und Stahlwerke, who have made many thousands of tons of rails and other products in the Roehling-Rodenhauser furnaces, and to whose work in this direction the development and production of a high-class electric steel rail is due.

It is true that the largest furnace at present working is one of eight tons capacity, which gives an output of 100 tons per day, but designs are completed for 16-ton furnaces and manufacture of the same will be put in hand very shortly.

NEW YORK CITY.

A. H. STRONG,

American Electric Furnace Company.

-ite and -Undum.

To the Editor of Electrochemical and Metallurgical Industry:

SIR:—When a new substance is to be named, I submit that the name to be invented should, in the interest of economy of time, space, and mental effort be short and distinctive, that is, different from others and easy to write, read, and comprehend.

The prevailing habit of giving to new substances names of from two to four syllables and ending in "undum" or "ite" or other "cribbed" ending, is surely wrong, and your readers include offenders addicted thereto.

A suitable name of four letters and of one or at most two syllables can usually be made up either arbitrarily or by using one or two letters from each of the chief words which might describe or suggest the new thing.

The ending "ite" should be reserved for minerals alone, where its necessary repetition causes waste, but where it is firmly entrenched by long acceptance and usage. To the layman all words ending in "undum" look alike.

Herbert Spencer noted that our language was made much easier to read because of the dissimilarity of the letters, they being of different shapes and heights, some extending above and some below the line, than if they were more uniform. The words as a consequence also have individuality. He also spoke of the force and convenience of short words.

Much irreparable damage has already been done in this line, but it is to be hoped that the amount will be made small in the future.

PLAINFIELD, N. J.

HENRY D. HIBBARD.

* Some figures of actual cost of power development in Norway are given on page 213 of this issue.—Ed.

The Works of the International Acheson Graphite Company at Niagara Falls.

Edward Goodrich Acheson shares with Charles M. Hall the honor of having founded the first electrochemical industries at Niagara Falls.

There is no necessity to describe in this journal Dr. Acheson's early pioneer work with carborundum and artificial graphite. A full illustrated description, by Dr. J. W. Richards, of the works and the process of the International Acheson



FIG. 1.—INTERNATIONAL ACHESON GRAPHITE WORKS.

Graphite Company in the summer of 1902 may be found in our Vol. I, p. 52 (October, 1902).

However, since 1902, the ever-active inventive genius of Dr. Acheson has brought about important developments in extending the applications of artificial graphite into fields of usefulness, undreamt of a few years ago.

It is perhaps not realized that the whole artificial graphite industry is only ten years old. The company was organized in 1899, with Mr. Acheson as president, which position he has occupied ever since. Other present officers of the company are: Mr. William Acheson Smith, vice-president, and Mr. O. E. Dunlap, secretary. The following sketch relates chiefly to the technical and industrial advances made by the company during the last seven years.

The development of the industry is indicated by the figures of power consumption. The company commenced the manufacture of graphite with 1000 hp. But this was soon found insufficient. In July, 1904, the plant was increased to 3000 hp, and now they are installing apparatus for using a total of 4000 hp. The fact that the almost universal business depression of the last year has not been felt at all by the company, is evidence of the soundness of this rapid development.

To indicate the manifold applications of artificial graphite, we mention only the following; it is used for electric work, as a powder for dry-battery filling, paint pigment, electrotyping, moulding and polishing, for the manufacture of lead pencils, for general lubrication, for rifle lubrication, and it is also mixed with grease and oil for lubricating purposes. Because of its remarkable purity, Acheson graphite, "Grade 1340," of which more will be said below, has come to be known as a perfect solid lubricant, and with the possibilities of "deflocculated

graphite," the future of artificial graphite in the field of lubrication appears destined to be amazing.

Without repeating what we have formerly published on the process, we shall describe in this article the present equipment of the works of the International Acheson Graphite Company.

The superiority of artificial graphite over natural graphite is essentially due to the greater purity obtained by carefully selecting the raw materials.* These raw materials are assembled in a three-story structure having dimensions of 100 by 50 ft. This building is almost wholly occupied by large steel bins, crushing machinery, mixers, together with scales to weigh each ingredient that enters "the mix" for charging the furnace.

The charge is transferred from the raw materials building to the furnace room in large steel hoppers, picked up and handled by electric cranes, which also dump or place the material in the furnaces. The furnace room has dimensions approximately 100 by 230 ft. and contains 22 furnaces† capable of consuming 4000 electrical hp continuously.

After the electric-furnace operation is completed, the mass is permitted to cool, and the work of unloading the furnaces begins. The graphite is loaded into steel hoppers, and these are picked up by electric cranes, and carried to the grinding and storage building, which is four stories high, 45 by 100 ft. in dimensions, at the south end of the furnace room, where the product is discharged into a conveyor by which the graphite is carried up into large steel bins provided for storage purposes.

From these bins the "lump graphite" is led by spouts to tube mills, where it is ground into powder form. As the powder leaves the tube mill it goes through the air separator, where the coarse particles are removed and only that which is of the desired standard of fineness is permitted to pass to the mechanical packer, where it is placed in barrels or bags, as desired, for shipment.

This description relates particularly to the battery filler, paint pigment, and similar grades, but in the case of Acheson graphite, grade "1340," there is a marked difference in its handling and treatment.‡ The claim is made that this graphite is the purest and best in the world, and in order to have the

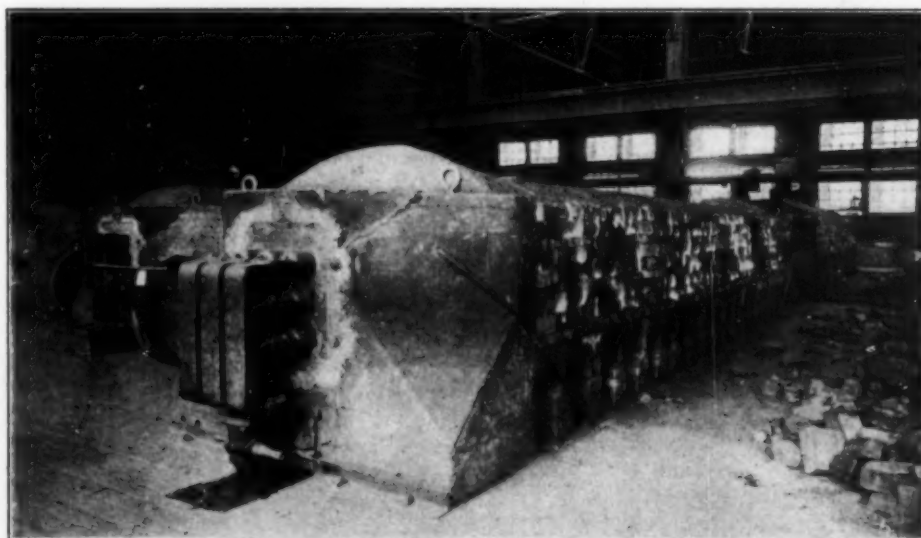


FIG. 2.—ACHESON GRAPHITE FURNACE IN OPERATION.

product support this claim every effort within human power is directed to maintain the highest standard ever set for a graph-

*See the article by Morris M. Green on the sources of raw materials for Niagara's electrochemical industries, our Vol. III, page 296.

†Concerning the design of the Acheson graphite furnace, see the article by F. A. Fitzgerald, in our Vol. III, page 416.

‡Concerning the special method of making soft, unctuous graphite, see our Vol. IV, page 502.

ite, which is a purity content of at least 99 per cent. While Acheson graphite, grade "1340," is guaranteed to be at least 99 per cent pure, none of this product is ever approved by the chemists in charge unless it ranges higher in purity content, its purity usually ranging close to 99.80.

The maintenance of this standard naturally requires extraordinary care and watchfulness. The raw material used, its loading into the furnaces, the operation of the furnaces, the cooling, all are features that demand and receive extra care, but even this watchfulness is increased when the time comes to unload a "1340" furnace.

Four men are selected to do the work. Each man is a picked employee. They bring into the furnace room large galvanized iron cans, known by them to be perfectly clean. The lids are down tight. The cans are placed right on the furnace, the walls of which have by this time been torn away. Two of the men have shovels. One handles a knife with a long and wide blade, while the sole duty of the fourth man is to raise and lower the lid of the can being filled.

The cans are numbered 1, 2, and 3, and into them is placed the graphite from a special section of the formation, the same number always indicating to the chemist and superintendent



FIG. 3.—SCENE IN PRODUCTS BUILDING.

the same special section of the furnace. The man with the knife indicates how far the furnace is to be uncovered, the distance not being great at any one time.

The shovelers do their work rapidly and carefully, the man at the can responding to their movements, shutting the lid down tightly the moment the shovel is withdrawn in order that dust or other impurities floating about the furnace may have no opportunity to get inside the cans. A surgeon performing an operation would not be more careful than are these men in the dissection of a "1340" furnace.

When filled, the cans of "1340" are removed from the furnace room to a special grinding room, better known as the lubricating department, where the graphite is disintegrated to a coarse powder. It is then passed through a concentrator to remove any hard graphite, after which it is placed in cans containing from 100 to 200 lb. and samples taken from each lot or package.

All of the samples are taken to the laboratory, which is located in a frame structure known as the Works Office Building, with the offices of the superintendent, the chief chemist, chemical and physical laboratories, and an electroplating department.

When the laboratory receives the samples of "1340," an ash determination is made by an assistant and the resulting ash turned over to the chief chemist for his examination, which consists in inspecting the ash carefully by microscope in order to determine if it has any gritty impurities. Should any be found, the lot from which the sample is taken is at once condemned.

If the ash content of the sample be less than 1 per cent and

no grit presents itself the lot from which the sample was taken is passed and is later ground in an impact pulverizer to an impalpable powder, the condition in which it is marketed.

However, as the "1340" comes from the mill the contents of each barrel is sampled very carefully. This new sample is sent to the laboratory and each barrel is held in bond until the laboratory approves the contents as being up to the high standard for this grade. This second analysis is made as a check on the first analysis as well as a safeguard.

When each barrel is approved by the laboratory as being up to the adopted standard it is released from bond and placed in stock.

In the manufacture of electrodes, etc., the various sizes are placed in the electric furnaces and graphitized, after which they are removed from the furnace to the shipping department in the products building, where they are boxed and shipped to all parts of the world. Concerning the process of graphitizing articles of carbon, like carbon electrodes, we refer to the descriptions of Richards and FitzGerald above quoted. As to the ease of machining graphite electrodes, see the article by C. L. Collens, 2d, in our Vol. I, p. 26.

The products building is 112 x 55 ft. in dimensions, four stories high. It is equipped with a large freight elevator, has electric light and is heated by steam. Large doors open on the north side to cars that stand on the tracks of the Niagara Junction Railway.

The bulk graphite, other than the "1340," is ground and stored in the new grinding and storage building previously mentioned.

In addition to the facilities recorded the company maintains and operates its own machine and blacksmith shops so that the works in their entirety are quite complete.

The plant improvements of 1908-09 have necessitated an expenditure quite considerable, which has given greatly increased output facilities. But there is still ample room for further extensions.

The most interesting and the latest development of artificial graphite is the invention by Dr. Acheson of a method for bringing graphite into the colloidal state. (For details see our Vol. V, p. 452.) This is done by treatment with a solution of gallotannic acid. In this condition the graphite remains permanently suspended in water or oil and is called by the inventor "deflocculated graphite." The suspension of deflocculated graphite in water has received the name Aquadag, its suspension in oil is called Oildag (the word dag being formed from the initials of "deflocculated Acheson graphite").

Aquadag was first developed and it was found by extended tests with aquadag as a lubricant that deflocculated graphite in water prevents the corrosion of iron and steel. Yet as Dr. Acheson wished to conquer the whole field, now covered by oil lubrication, he developed "oildag." It has already given most remarkable results in connection with automobiles; it reduces not only the oil consumption 50 per cent, but it increases considerably the available power and prevents pitting in the valves.

Oildag is constantly being subjected to new tests and it appears that the artificial graphite industry, after its splendid start with hard graphite in lump form and in form of graphitized carbon articles, has now entered, with soft unctuous graphite and aquadag and oildag, a career of unlimited possibilities.

It may be added that aquadag and oildag are products of the Acheson Oildag Company, which company controls the deflocculated graphite products.

Many well-deserved honors have been conferred on Mr. Acheson to show to him the appreciation of the scientific world. For the past year he has been the president of the American Electrochemical Society and at Lincoln's Birthday the University of Pittsburgh conferred on him the honorary degree of Doctor of Science, a tribute well deserved.

Alkali Chloride Electrolysis in Europe.

(From Our Berlin Correspondent.)

An interesting lecture on alkali chloride electrolysis was held on March 13 in the Hofmann House, in Berlin, by Prof. B. LEPSIUS, director of the Griesheim-Elektron Company.

In 1892, at the electrical exhibition in Frankfort-on-Main, the Griesheim company first exhibited electrolytic caustic soda. Numerous experiments and tests had been necessary to reduce Hoepfner's diaphragm process to commercial practice. The chief difficulties which had to be overcome were found in the manufacture of suitable cement diaphragms and carbon anodes. The carbon anodes, which weigh 15 kg (33 lb.), are made by pressing a mixture of lampblack and tar into suitable forms and baking them in porcelain furnaces; they last for about a year.

Professor Lepsius discussed the following three processes: the diaphragm process, the mercury-cathode process and the gravity process (glockenverfahren).

In diaphragm cells the cathodes are generally made of iron. In the Griesheim works the small sheet-iron boxes, in which the anode cells are suspended, are themselves the cathodes.

In the diaphragm process operation must be stopped when the proportion of caustic alkali in the catholyte has risen to 8 per cent, otherwise the amp-hour efficiency will be unduly reduced and oxygen will be set free at the anode, forming carbon dioxide which mixes with the chlorine gas.

This last disadvantage has been overcome in recent years by the use of ferric oxide electrodes,* made by melting iron oxide in an electric arc furnace. Much care was necessary to produce large electrodes and to prevent their cracking. With this improvement the evolution of oxygen at the anodes at 70° to 80° now results in the formation of potassium chlorate which crystallizes out and is removed from the cell from time to time. When the catholyte has reached a content of 8 per cent free alkali it is run off and fresh sodium chloride solution is filled in.

The caustic soda contains iron chloride, etc., as impurities. It is purified by osmosis on the counter-current principle; "the impure solution is passed through long gutters and brought in contact with water. The caustic diffuses quickly and is extracted, while the impurities remain back."

The Griesheim Company has built a second factory in Bitterfeld, near the large potassium salt deposits of the province of Saxony, where coal is also mined; the cost of power is here only one-half the cost in Griesheim, where Westphalian bituminous coal is used. A plant of the Allgemeine Elektrizitäts Gesellschaft, also located at Bitterfeld, and works of the Griesheim-Elektron Company at La Motte, near Compiegne, France, and near Barcelona, Spain, also use the same process. The Badische Anilin und Soda Fabrik also has a plant with this process in Westeregeln; the chlorine is here used in the manufacture of artificial indigo.

The Griesheim diaphragm process is now employed in works using 33,000 hp and producing per year 70,000 tons of caustic.

Professor Lepsius then discussed the Castner-Kellner mercury-cathode process.

If the anode compartment (in which chlorine is set free and sodium alloys with the mercury which here forms the cathode) and the cathode compartment (in which the sodium amalgam gives off its sodium, forming caustic soda and hydrogen) are electrically connected in series, a difficulty is experienced on account of the fact that a small portion of the sodium in the anode compartment does react with the chlorine. For this reason there is a deficiency of sodium in the cathode compartment. If the same current is used in the anode and in the cathode compartments there is not enough sodium in the amalgam to be changed into caustic soda in the cathode com-

partment. Hence part of the mercury will be oxidized. This must, of course, be prevented.

Two remedies are possible. The first is to shunt the cathode compartment by a proper resistance so that the current in the cathode compartment is less (by 14 per cent, according to Professor Lepsius) than in the anode compartment. The second is to short-circuit directly the amalgam with the iron cathode in the cathode compartment.

In the Salvay mercury process the amalgam runs off in a continuous stream and is chemically decomposed in a separate vessel.

The advantages of the mercury process are that there are no diaphragms; that the catholyte is very pure and may contain up to 20 per cent caustic soda; that the amp-hour efficiency is high, and that the anodes have a very long life. Disadvantages are the higher voltage (4.3 volts against 3.5 with the Griesheim process, according to Lepsius), the greater complication of the apparatus, and the large quantity of mercury required. For a 3000-hp plant 72,000 kg of mercury are required.

The gravity process (glockenverfahren) has been worked out by the Oesterreichische Verein für Chemische und Metallurgische Produktion in Aussig. This process is said by Professor Lepsius to have the following disadvantages: The current density is low so that an extended system of apparatus and a large area are required, and the voltage is high, 4 volts. In Aussig 25,000 bells are said to be in operation at about 3000 hp.

If the caustic may be considered to be the chief product of alkali chloride electrolysis, the chlorine is an important by-product. Chlorine is also made on a commercial scale by passing hot magnesium over chlorine, whereby magnesia is formed and chlorine is set free; at present about 10,000 to 13,000 tons of chlorine are still made from magnesium chloride.

In the Deacon process, which was formerly of great importance, hydrochloric acid gas is conducted over hot copper salts; at present the only German works making chlorine by this process is the Rhenania Company in Aix-la-Chapelle.

Most of the chlorine is now made by alkali chloride electrolysis. It is partly liquefied and shipped in bottles or tank-cars of several thousand kilograms content. But the greatest part of chlorine is used for bleaching-powder manufacture.

More recently crystallized calcium hypochlorite is obtained at Griesheim by more carefully evaporating the chloride of lime solution; since it contains much more active chlorine it is more valuable than bleaching powder.

Other products made from electrolytic chlorine are carbon tetrachloride, tin tetrachloride, chloral, chloroform, etc.; it is also used in large quantities in the artificial-indigo industry.

There is very much less demand for the hydrogen gas set free at the cathode. The chief consumer in Germany is at present the air-ship industry. There will be an air-ship exhibition this summer in Frankfort-on-Main and the Griesheim Company will furnish every day 1000 cu. mm (35,000 cu. ft.) of hydrogen—free of charge. Another application of hydrogen is for welding and cutting with the oxy-hydrogen flame.

While Professor Lepsius had intended to speak on the application of electrolysis in chemical industries, in general, lack of time forced him to restrict his remarks to alkali-chloride electrolysis. There was an interesting exhibition of various products of electrochemical industries.

The Works of the Carborundum Company at Niagara Falls.

Carborundum may properly be called the pioneer electric furnace product. It shares with calcium carbide the distinction of marking the beginning of the electrometallurgical art founded on the chemistry of high temperatures.

The Carborundum Company was organized in 1893 by Pittsburgh capitalists to work on a large scale at Niagara Falls the process of Mr. E. C. Acheson, for making silicon carbide or

*See patent of H. Specketer, our Vol. III, p. 392.

carborundum. The early development of the process and the achievements of the Carborundum Co. up to 1902 were described in full, with numerous illustrations, in an article by Dr. Jos. W. Richards, in our Vol. I, p. 50 (October, 1900). There exists also an excellent monograph on carborundum by Mr. F. A. J. FitzGerald, published as Volume XIII of the German series of monographs on applied electrochemistry (Halle a. S., 1904).

However, since that time, the carborundum industry has made rapid advances. Under the progressive management of its president, Mr. F. W. Haskell, the Carborundum Company has been able to create a rapidly widening field of usefulness



FIG. 1.—FURNACE BUILDING OF CARBORUNDUM COMPANY.

and a steadily increasing demand for carborundum so that this electric-furnace product, absolutely unknown twenty years ago, is now indispensable in the most varied industries.

Technical advances have kept pace with commercial progress; they are the result of a series of able and important inventions of Mr. F. J. Tone, the works manager of the company. The former apparatus has been improved, the process has been modified in various respects, and new processes have been worked out for the manufacture of other electrometallurgical products besides carborundum.

The following sketch of these very interesting developments will, therefore, be welcome to our readers. We have avoided to repeat well-known facts or well-known pictures, as they are easily accessible in the publications referred to above. The

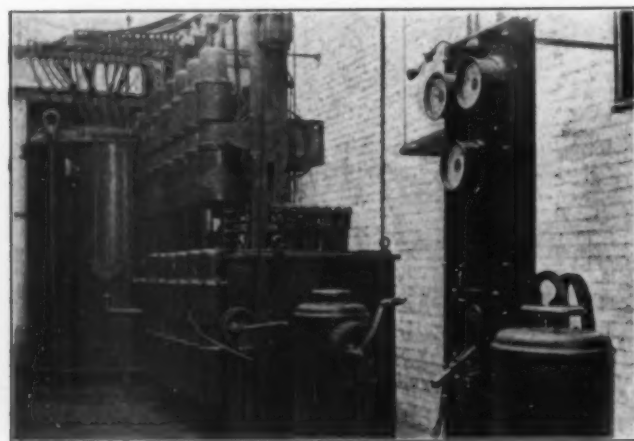


FIG. 2.—1600-KW TRANSFORMER.

object of the following article is to sketch only the new developments of the last years.

Carborundum.

The first commercial carborundum furnace as operated in 1893 was a loosely constructed box of fire brick, consuming 75 electrical hp and producing in each run about 50 lb. of car-

borundum. The furnace employed to-day utilizes 2000 hp and has an output of 15,000 lb. of crystalline product in each run. The annual production in 1892 was 2145 lb. In 1907 it was 7,532,670 lb.

The present electrical equipment of the Carborundum Company for the manufacture of carborundum has a capacity of 7000 hp. This consists of 1000 and 2000 hp units, each electrical unit being connected to a series of furnaces of the same capacity. The transformers are of the water-cooled type with a rating of 1600 kw and receive the primary current at a voltage of 2200 and a frequency of 25 cycles. The secondary voltage is capable of a wide range of regulation. This is accomplished by the cutting out of primary coils by means of oil switches which are actuated by solenoids. These solenoids are all controlled from a master controller which operates them in regular order by the revolution of the controlling drum. The transformers are located close to their respective lines of furnaces, but are controlled by one attendant from a central room in which the meters and controllers are located.

The present type of furnaces is constructed of sectional walls of fire brick set in iron frames.* These sections are assembled and taken down by means of an overhead crane, and in this way the labor incident to intermittent furnace operation has been greatly reduced. The mixture is charged into the furnace by an overhead conveyor. One main line of conveyor leads

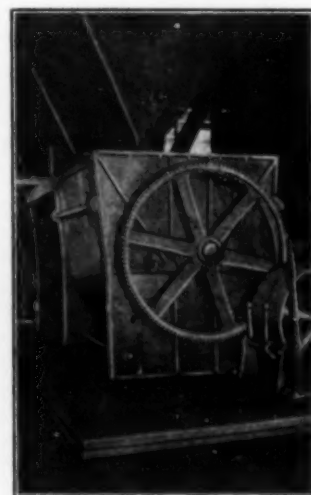


FIG. 3.—MIXING CARBORUNDUM CHARGE.



FIG. 4.—LINE OF FURNACE CONVEYORS.

from the mixing-room over the several furnace units, and from the main conveyor extend branches over each furnace unit so arranged that any furnace may be loaded therefrom. A furnace unit consists of five furnaces, only one of which is

* F. J. Tone, Patent No. 800,515. See our Vol. IV, p. 502. Concerning the fundamental principles of the design of the carborundum furnace see the article by F. A. J. FitzGerald, in our Vol. IV, p. 53.

operated at a time, the others being in the process of cooling, discharging or loading, as the case may be.

The first use of carborundum was as a substitute for diamond powder and for the manufacture of dental wheels. From this limited field its uses have extended into many arts, mechanical, chemical and metallurgical, but its application as an **abrasive**

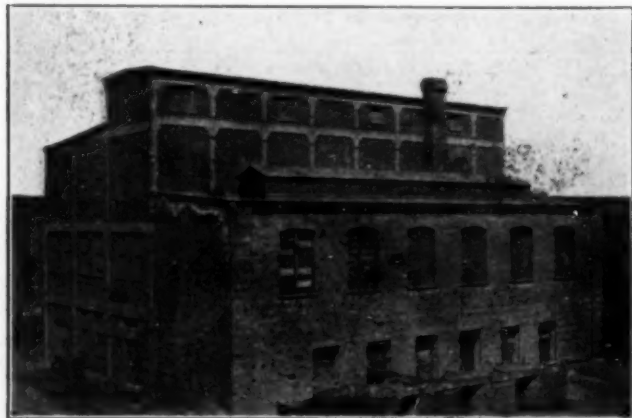


FIG. 5.—GRADING BUILDING.

is still of chief importance and consumes the major portion of the production. The infinite variety of grinding operations into which carborundum enters is worthy of note. It is used not only for the grinding of all classes of metal, but for all conceivable forms of wood, leather, paper, pearl, stone and almost every substance which requires to be shaped or polished.

A large portion of the world's marble production is now cut and shaped by carborundum wheels. The slab of marble which in former practice was molded by laborious hand methods is now passed through machines and cut to molds of the most intricate profile at the rate of 10 ft. per minute.

Paper pulp is now refined by carborundum. Huge carborundum blocks are placed in the beaters and the abrasion of the



FIG. 6.—SIFTING CARBORUNDUM.

moving pulp upon these blocks draws out and opens up the fiber.

Non-slipping stair treads in public stairways and building entrances subjected to heavy travel are widely used, the method in this country being to insert in iron or steel plates strips of carborundum grains set in a matrix of cement. In France carborundum grains are now used as a top dressing in cement blocks and walks and a careful observation of three steps in the Gare-de-Lyon, a Paris railway station, shows no perceptible wear in fourteen months after the passage of fourteen million travelers.

Carborundum has in recent years developed many uses outside of the abrasive field which strikingly illustrate its diversi-

fied properties. Molded into the form of rods it is used as resistance units by the electrical manufacturers in the construction of lightning arresters. A carborundum wireless detector has been developed which is used in a large number of the wireless telegraph stations of the De Forrest Company.

The **refractory** applications of carborundum are also of



FIG. 7.—TAPPING A SILICON FURNACE.

importance. Outside of the crystalline zone of the furnace is a zone of green amorphous-like material which contains carbon, silica, and oxygen, in the form of various compounds representing the partial reduction of silica by carbon and having the chemical formula $\text{Si}_2\text{C}_2\text{O}$. It is much used in brass and oil-burning furnaces. Zinc muffles made with an interior lining of carborundum are largely used on the Continent.

Carborundum has been found by recent experimenters to have an index of refraction higher than that of the diamond.

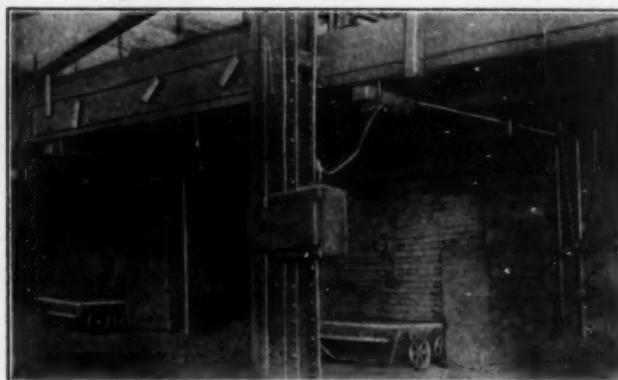


FIG. 8.—TAPPING FLOOR OF SILICON FURNACES.

This fact makes its optical properties a matter of great interest, and the use of carborundum as a gem would be quite possible if it could be produced in a transparent form and in crystals of considerable size. The brilliancy or fire of a precious stone

is in direct proportion to its refractive power, and transparent carborundum excels all known substances in its ability to break up light.

Among the new products of carborundum may be mentioned a dense or compacted form which may be produced by several processes. One process for the manufacture of this form is described in a recent patent of F. J. Tone, No. 913,324 (see our April issue, p. 167). This form of carborundum has very great toughness, but is not as hard as the regular form. A similar material has been recently described in our January issue, p. 24, under the name of "silundum." Its electrical conductivity is greater than that of the common form of carborundum and as a resistance element in electrical heaters, cooking apparatus, and other forms of resistors it has important applications.

The Carborundum Company are now making many abrasive products besides carborundum. During the past year they have entered into the manufacture of garnet paper and cloth, emery paper and cloth and corundum wheels. A new artificial abrasive is also being produced by an electric-furnace process from aluminium silicate.* This product has been given the name of "aloxite" and consists principally of fused alumina.

The process of manufacture consists in smelting a mixture of a pure aluminium silicate, such as kaolin, carbon and iron oxide, the carbon being so proportioned as to reduce the silica but to leave the alumina unreduced. The reduced silicon unites with the iron to form ferrosilicon, while the alumina is fused and freed of practically all of its impurities. A furnace is used with two depending vertical electrodes, the furnace struc-

ture settles to the bottom of the furnace, from which it may be tapped.

Silicon.

The Carborundum Company has been the first to produce pure silicon commercially, the process for its manufacture having been developed by its works manager, F. J. Tone, U. S. Patents 745,122, 833,427, 842,273 and 869,276 (see our Vol. II,

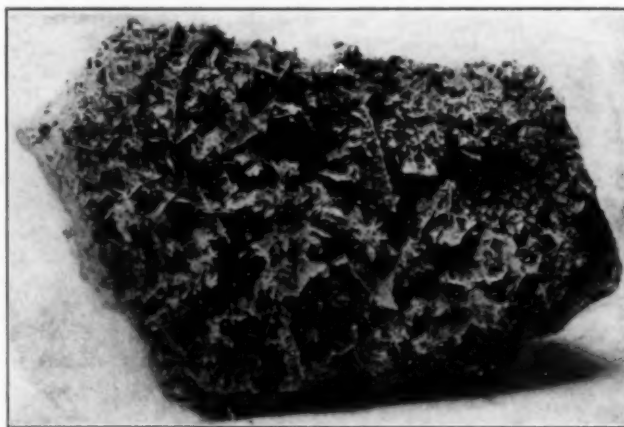


FIG. 10.—SILICON CRYSTALS FROM CAVITY OF PIG OF SILICON.

p. 111; IV, 464; V, 141). The production is now carried on by the company on a large scale.

The furnaces used are large arc furnaces having two depending vertical electrodes extending a considerable depth into the charge, which consists of coke and sand. The furnace structure is of fire brick, lined on the interior with carbon. Each furnace has a capacity of 1200 hp and the metal is tapped out at intervals of a few hours in pigs of from 600 to 800 lb.

Silicon is made in grades containing 90, 95 and 97 per cent silicon. The following are typical analyses of some of these grades:

Silicon	90.60	95.71
Iron	6.70	2.24
Manganese08	...
Aluminium	2.35	1.96
Phosphorus02	.01
Carbon22	.08
Sulphur00	.00

The principal use of the 90 per cent silicon metal is in the refining of steel where it replaces the higher grades of ferrosilicon. It accomplishes the deoxidation of the metal in the most efficient manner. About five hundred tons of 90 per cent silicon metal have been sold for this purpose during the past year.

Another important use of silicon is as a reducing agent in the manufacture of low-carbon ferro-alloys, such as ferro-vanadium, ferrochromium and similar alloys. Silicon has a greater deoxidizing capacity per unit of weight than aluminium and is, therefore, very efficient for this purpose.

An alloy of calcium and silicon which is now being introduced into the steel trade for the refining of steel is produced by the reduction of calcium oxide by silicon. This has called for a small tonnage of the material and will doubtless increase.

With constantly decreasing cost, silicon is destined to become a metal of common use. When the problem of its manufacture was first undertaken it sold at \$4 per pound. It is now marketed in carload lots at about \$120 per gross ton.

Its use will be greatly extended when certain problems are solved in connection with its industrial applications. One of the most important of these problems is the production of silicon castings.

Such castings would be of great utility as acid containers and for the manufacture of various kinds of apparatus which



FIG. 9.—AN 800-LB. PIG OF SILICON.

ture being built of fire brick, the receptacle being open on top to permit the feeding in of the charge.

After a large ingot of the material has been formed, the operation is stopped and the furnace cooled. The aloxite is broken up and crushed and thereafter treated in the same manner as other abrasive materials. The ferrosilicon for the most

* F. J. Tone, U. S. Patents 906,172, 906,173, 906,338 and 906,339 (see our January issue, p. 35).

are subjected to the action of acid and are widely used in the chemical industries.

There will undoubtedly be a large market for such silicon or silicide containers when the technical difficulties of casting silicon have once been overcome.

Silicon is now produced in the form of small castings, such as rods for electric resistances, but it is difficult to cast perfect forms unless the section is thin. Castings of considerable thickness are porous and subject to shrinkage strains. Resistance rods $\frac{1}{4}$ in. in diameter are easily cast in lengths of 12 in., and several of these rods may be electrically welded together to form longer resistances.

Aluminium Welding.

By M. U. SCHOOP.

In my article in the April issue of this journal I have given an outline of my method of autogenous welding of aluminium. In the present article I will deal chiefly with the field of application of this process and with the types of burners specially suitable for the process.

First, however, I wish to refer again to the method of Heraeus, who was the first to weld aluminium. His method is based on the fact that at a certain temperature (around 550 deg. C.) aluminium softens and that in this plastic condition it can be united or welded with a similarly heated piece with the aid of hammering. The fundamental principle is, therefore, the same as that of the very old iron-welding method with which every blacksmith is familiar.

The characteristic feature of the method of Heraeus is the maintenance of an exact temperature. At too low a temperature no union is obtained, while at too high a temperature the aluminium gets brittle or softens and spatters away under the hammer.

To employ the correct "critical temperature" is purely a matter of experience and skill, and for this reason the use of the method involves difficulties, especially if sheets of less than 2.5 mm (one-tenth of an inch) are to be welded, and if aluminium alloys, like magnesium, partinium, etc., are to be welded.

Articles welded according to this method were first exhibited at the World's Fair in Paris, in 1900. As a matter of curiosity it may be mentioned that there exists a U. S. patent for a process which is identical with that of Heraeus. It is No. 710,958 of March 21, 1901, granted to M. Wisniewska, and claiming "the process of welding aluminium which consists in bringing the thoroughly cleansed parts of aluminium to be united into contact, and applying heat to the same until the metal begins to soften, whereby they may be welded or permanently united."

A patent for welding aluminium, which is not without a certain interest, is the German patent, No. 109,433 of 1899, which refers to a "process of welding aluminium and aluminium alloys with or without flux or reducing joints." At the moment

of welding it is intended to tear or remove mechanically the oxide film formed during heating. It is recommended to use an electric current whereby one pole is connected to the articles to be welded and the other pole to a suitable carbon electrode. It is said that by this method the aluminium oxide is electrolytically decomposed and the welding process accelerated. The pressure applied is 6 to 8 volts.

I have tried to weld aluminium according to this patent, but have been unsuccessful, although I have been familiar for many years with methods of welding iron and lead (Electrochemical and Metallurgical Industry, 1905, p. 260, on Autogenous Lead Soldering). Though the melting coil of lead in degrees Centigrade is just one-half that of aluminium (330 deg. for lead and 650 deg. for the aluminium, and the thermal conductivity of lead is less than that of aluminium, yet the current may rise to 50 or 60 amperes, when welding lead sheets of 2 mm (80 mils) in thickness. If aluminium sheets can really be welded by this method, the current consumption will probably be so high that the process will hardly be commercially practical.

In several patents (for instance, the Belgium patent of Mazzucchelli, 206,355, of 1908) it is proposed to remove the oxide film formed on heating by mechanical means, by scraping with suitable instruments. If thick, solid articles are to be welded it is possible to break through the superficial oxide film with an instrument, and to cause in this way a union of the parts of aluminium. But with thin sheets this method cannot be used.

There are some other patents for welding aluminium of a more or less hypothetical character. But of methods for soldering aluminium there exist an enormous number, which indicates the activity in this field and the demand for a simple and reliable method for soldering or welding aluminium.

Without discussing in detail these patents, I will say that by far most of the joints made by soldering aluminium will lose after a short time their original strength; and this is always the case if the solder contains tin.

A quick method of determining the quality of an aluminium joint is to place the article into hot acidulated water, whereby the evolution of little hydrogen bubbles can be directly observed with the eye. This is due to local electrolytic action whereby the joint will be decomposed. This electrolytic action will progress rapidly, if in the galvanic metal series the foreign metal in the solder is removed from aluminium.

The future will show whether it will ever be possible to find an aluminium solder, satisfactory in every respect, and which would correspond to the universally used solder (lead and tin) for soldering copper, iron, etc., and the application of which would simply require the use of the blow-pipe. On the basis of more than 1000 experiments which I have made, I doubt the possibility of finding such a simple solution.

Applications of Aluminium Welding.

Chemical and electrical engineers are interested in the first place in the manufacture of large aluminium vessels, for evaporating and distilling. They are even preferred to nickel



FIG. 2.—WELDED ALUMINIUM CONTAINER.

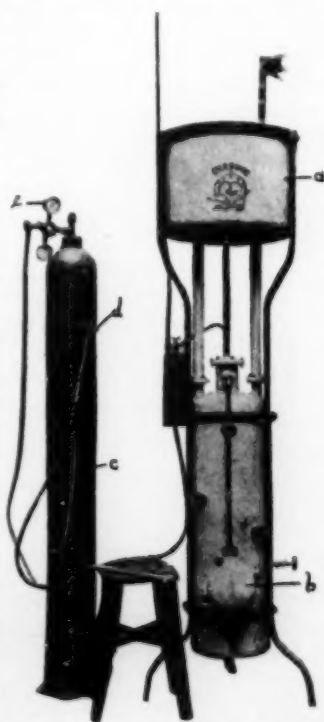


FIG. 1.—OXY-ACETYLENE WELDING OUTFIT.

and copper vessels on account of their lower price and lighter weight. In breweries, the containers made of wood or of enameled iron plates are being replaced advantageously by welded aluminium containers. Continuous contact with the aluminium metal does not result in the so-called "yeast poisoning," which occurs with most other metals. In general, in hygienic and sanitary respects, aluminium is the ideal metal. For this reason, cooking and kitchen utensils of aluminium have found very much favor with the general public within a comparatively short time.

Aluminium has a high resistivity against most acids. According to Prometheus, the German army workshops have been using for the last three years aluminium vessels for working with acids, and the results have been very satisfactory. Nitric acid or sulphuric acid and their hot vapors attack aluminium only slightly, and after two years of use the vessels could still be satisfactorily used. From former experience with brass, copper, and bronze vessels, these had to be replaced in the same time by new vessels. The use of aluminium vessels in working with acids results, therefore, in considerable saving. An additional advantage of aluminium vessels is that they are of lighter weight and can be easily handled.

The Aktien Gesellschaft für Aluminiumschweissung in Zurich has carried out a long series of tests in order to determine the attack of aluminium by acids, especially by nitric acid. The results may be briefly summed up by stating that the attack of aluminium by nitric acid is greatest for an acid concentration of 30 per cent, and this attack will go on the more rapidly the greater the impurity of aluminium, other things being equal. With lead the situation is similar.

Of the different kinds of aluminium made in Europe, the English metal was found to be the best, and was least attacked by acids. As an example, I may mention comparative tests made with 100-per-cent acetic acid which showed a loss of weight per 100 sq. cm surface of 1.66 mg for English sheet aluminium, and 5.77 mg for Swiss sheet aluminium.

A typical analysis of English sheet aluminium is 0.312 per cent silicon, 0.256 per cent iron, 0.096 per cent tin, hence total impurities 0.644 per cent, so that aluminium is 99.34 per cent pure.

It is certain that not only the chemical composition, but also the structure and the condition of the surface of the sheet aluminium are of importance with respect to the attack by acids. The following experiments will show this.

Take three hard-rolled sheets of aluminium of equal size, of which I is carefully polished, II has a frosted surface, while III is heated over a Bunsen burner, until a chip of wood begins to char. These three sheets of aluminium will behave very differently in an acid bath.

Number I is attacked least, and number III most. Number III is very similar to cast aluminium and has a lower specific weight and a more crystalline structure than the rolled and hard material of I and II.

Extended fields of application of aluminium containers are aeronautics and the automobile industry, the yacht industry, the manufacture of vacuum apparatus, montejus and other apparatus for chemical industries, of iron containers with an aluminium lining, etc. Aluminium is also especially useful for

apparatus of the fat, glycerine, and stearine industries, for transportation vessels of all kinds, for cooling and heating pipes, for extraction apparatus, etc.

Burners for Welding.

Concerning the most suitable type of burner and the most suitable gaseous fuel, there may be a difference of opinion. For thick aluminium sheets it is advisable to use the oxy-acetylene burner which permits the production of intensive local heat effect within a short time. Fig. 1 represents the apparatus of Michel-Molas, of Paris. The water is filled into *a*, the carbide into *b*, *c* is a steel container for compressed oxygen (125 atmospheres), *d* the burner and *e* the manometer.

For welding thin sheets, the oxy-hydrogen blowpipe is sufficient, or the oxygen-illuminating gas blowpipe. The last one is especially useful in places where illuminating gas is available, as nothing more is required but a compressed-oxygen container with a reducing valve, several feet of rubber pipe, and the blowpipe.

For welding iron sheets the composition of the illuminating gas (its contents of sulphur, phosphorus) has some influence on the result. On the other hand, at least according to my experience, the quality of the gas is of no importance for aluminium welding. But it is important that the two gases leave the burner as an intimate homogenous mixture. This requirement almost contradicts the other practical requirement that, for the sake of safety, the two gases should mix only just before they leave the burner.

Backlighting may be avoided if the speed with which the gas mixture flows out of the burner is greater than the speed of propagation of the explosion.

For smaller welding work, so-called "saving burners" (Sparbrenner) have proven quite satisfactory, in which the flame is automatically reduced in size as soon as the workman puts the burner aside; the oxygen supply being cut off entirely, and the hydrogen supply being reduced to such an extent that only a small flame remains burning. (See Swiss patent 41,627, Chalumeau a gaz, 1908.)

Those readers who want to learn more concerning the burner problem, may be referred to the recent excellent German book of Th. Kautny, "Handbuch der autogenen Schweissung," published by Marhold, in Halle a. S.

There is no special difficulty in the practical application of autogenous aluminium welding. Especially men acquainted with lead burning, skilled in handling the burner and careful



FIG. 3.—WELDED ALUMINIUM CONTAINER.

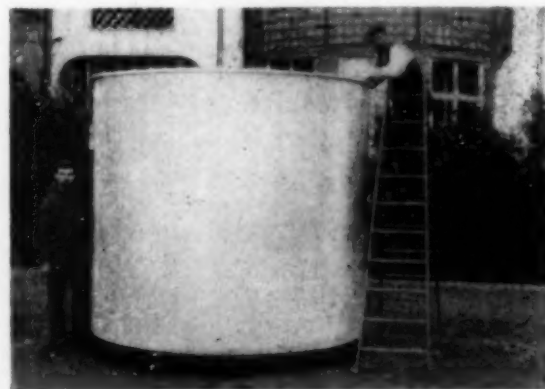


FIG. 4.—WELDED ALUMINIUM CONTAINER.

in observing the operation, will learn to weld aluminium within a few days.

With some skill it is also possible to avoid the tensions within the material which easily may develop in the case of thick sheets or in repairs of thick pieces, like automobile motor cases.

GARENNE-COLOMBES, near Paris, France.

Conductivity and the Valuation of Electric Conductors.

By E. F. NORTHRUP, PH.D.

When solid, round copper conductors of easily determined conductivity were almost exclusively used for transmitting electric power, it was not difficult or confusing to estimate their relative values as conveyors of energy. But now, we find competing with solid copper conductors, stranded, aluminium and bimetallic conductors. This variety of competing conductors, when taken in connection with the two methods in vogue of defining conductivity, has led to a certain confusion of ideas as to the precise meaning of conductivity and the best way of determining and stating the relative worth to the user in dollars of conductors of different qualities and types.

Assuming the above to be true, a clear statement of the accepted definitions of conductivity and the necessary relations which follow from these definitions will not be without value in assisting to a better understanding of how to estimate the relative worth of different electric conductors. We shall attempt this, and add a brief account how conductivity may be measured most conveniently and accurately.

The electrical engineer considers that the sole function of an electric conductor is to convey electric power from the generator of the power to the translator of the power. Thus viewed, that conductor will be the best one to use which will transmit a given power, a given distance with a specified loss, and cost the least money. The loss of power is proportional to the ohmic resistance of the conductor, and it is essential to be able to determine the relation between the resistance of a given length of any conductor, and the price at which such conductor, of given length and resistance, may be purchased. This relation is seldom given directly in price lists. The catalogs of leading wire manufacturers quote prices for their product as so many cents per pound for conductors of certain sizes, or so many dollars per 1000 ft. for conductors of specified diameters. They generally add a statement of the guaranteed per cent conductivity of the material, often neglecting, however, to state the standard of conductivity upon which their guarantee is based.

We shall first give under one general view the accepted definitions and the necessary relations that follow, so anyone can easily compute the relative power-conveying value of any conductor from the data as given in catalogs and price lists, however they are presented, provided this data is sufficient.

General and Specific Properties.

Electrical conductance is a general property of an electric circuit, and is the reciprocal of electrical resistance, or

$$C = \frac{1}{R} \quad (1)$$

where C is conductance and R is ohmic resistance.

The dimensions of C are $L^{-1}T$ in electromagnetic measure and LT^{-1} in electrostatic measure, the one being the reciprocal of the other. Commercially, conductance is considered only in electromagnetic measure.

Since resistance is equal to the e.m.f. E divided by the current I , conductance is defined by the relation

$$C = \frac{I}{E} \quad (2)$$

If E is made equal to a unit potential difference between the terminals of any conductor, then conductance becomes a measure of the current which flows between the same terminals. As thus defined, *conductance* is a general property of *electric circuits* and in no way defines the current-carrying quality of the material forming the circuit.

We may treat, however, of the property of the *conductor* whereby its quality is considered as a conveyor of electric current, but the term which should be used then is *conductivity*. As specific gravity is the relation of the density of a substance, in its actual state, to the density of water under specified conditions, so conductivity is the relation of the conductance of

one conductor in its actual state to that of another conductor of like length and cross-section or like length and weight under specified conditions of temperature and resistance.

The conductor with which other conductors are compared, for finding their conductivities, is taken as a conductor having standard conductivity and called the standard conductor. When this standard conductor is specified in a particular way in respect to temperature, resistance, length and cross-section, or length and weight, it is defined to have unit conductivity. Instead of the term conductivity, the term "per cent conductivity" may be used, this latter being equal to the former multiplied by 100. Though the term "per cent conductivity" is the more generally used, we shall make our calculations using the term conductivity to avoid the repeated use of the multiplying factor 100.

The dimensions of conductivity when expressed by the meter-millimeter standard are $L^{-2}T$ in electromagnetic measure and T^{-2} in electrostatic measure. Hence, in either the electromagnetic or the electrostatic system of units conductance = conductivity (by the meter-millimeter standard) \times length. When conductivity is expressed by the meter-gram standard its dimensions in electromagnetic measure are LTM^{-2} , and, as will more fully appear later, conductivity by the meter-gram standard is proportional to conductivity by the meter-millimeter standard divided by a density.

Standards of Conductivity.

In every determination of the conductivity of any sample conductor, a comparison is made of its conductivity with that of an adopted standard. It is absolutely essential to be clear as to the standard of conductivity which has been adopted and the manner in which it is defined. The standard universally used in this country was recommended by the Standard Wiring Table Committee, Jan. 17, 1893. It is known as Matthiessen's standard. This standard is defined, however, in two distinct ways, and it would seem more proper to use the plural. Expressed in the forms most convenient for calculation, Matthiessen's standards as defined by this committee are as follows:

In respect to diameter, Matthiessen's standard of electrical conductivity is 1 m of round soft-copper wire of uniform cross-section, 1 mm in diameter, and having a resistance at 0° C. of 0.0203 international ohm. This definition applies equally to a wire of uniform cross-section, which may not be round, when the cross-section is $\frac{\pi}{4}$ sq. mm.

In respect to weight, Matthiessen's standard of conductivity is 1 m of soft-copper wire, which weighs 1 gram and has a resistance at 0° C. of 0.14173 international ohm. This definition presupposes a uniform cross-section of the wire.

Either or both of these two standards of Matthiessen are frequently used indiscriminately in making measurements of the conductivity of copper conductors, upon the confused assumption that they are equivalents, or only two ways of expressing the same thing. For these two standards to be equivalents a certain density for soft copper must be arbitrarily assumed. If the copper conductors of which the conductivity is sought happen to have this particular density, then and then only will the same result be obtained whichever standard is used in making the measurement. To show this, call A the meter-millimeter and B the meter-gram standard.

- Let δ = the density of the copper of standard B .
- " L = the length of standard B .
- " s = the cross-section of standard B .
- " W = the weight of standard B .
- " l = the length of standard A .
- " S = the cross-section of standard A .
- " D = the diameter of standard A .

Let r_a be the resistance at 0° C. of standard A and r_b the resistance at 0° C. of standard B . We have

$$\frac{r_0'}{r_0} = \frac{LS}{l_s}, \quad \text{also } S = \frac{\pi D^2}{4} \quad \text{and } W = sL\delta$$

from which relations

$$\delta = \frac{4r_0'W}{r_0\pi L^2 D^2} \quad (3)$$

In Matthiessen's standards

$$\begin{array}{lll} L = 100 \text{ cm.} & l = 100 \text{ cm} & r_0' = 0.14173 \\ D = 0.1 \text{ cm} & W = 1 \text{ gram} & r_0 = 0.0203 \end{array}$$

These values placed in (3) give

$$\delta = 8.8895 + \text{which equals } 8.89 \text{ within } 0.0056 \text{ per cent.}$$

It may be noted that the meter-gram standard when in the form of a round wire of density 8.89 is 0.3785 mm in diameter.

Now, assume a round wire 1 m long and 1 mm in diameter and of a measured resistance at 0° C. equal to r . In this case its conductivity is found by comparing directly its conductivity with that of standard A . If C_s is the conductivity sought, we have

$$C_s = \frac{1/r}{1/0.0203} = \frac{0.0203}{r}$$

If the weight of the wire instead of the diameter is given, this weight being 1 gram, and its density not known, its conductivity can only be found by comparing it directly with that of standard B . Calling C_w the conductivity sought, if the wire has a resistance r as before, we have

$$C_w = \frac{1/r}{1/0.14173} = \frac{0.14173}{r}$$

Now this wire might be of light material or of copper in the form of a tube so as to have an outside diameter of 1 mm, as in the former case. If such were true, and the density not considered, one might be led to use, in finding the conductivity,

either standard A or standard B . But since $\frac{C_w}{C_s} = \frac{0.14173}{0.0203} = 6.9817$, the result would be nearly seven times as large in the latter as in the former case. As will appear more fully later, if the diameter or cross-section and length only of a conductor are given, the meter-millimeter standard must be used in stating its conductivity, while, if the weight and length only are given, the meter-gram standard must be used.

To find the conductivity of a conductor in terms of one standard, when the conductivity of this conductor is given in terms of the other standard, necessitates a knowledge of the density of the material. If this density is 8.89, which is the basis upon which the meter-gram standard is connected with the meter-millimeter standard, then and then only will the conductivity of the conductor be the same to whichever of the two standards it is referred.

Thus if a wire manufacturer is turning out a uniform product of copper wire of density 8.878, which is stated to have a conductivity of 1 as referred to the meter-gram standard, this same wire would have a conductivity of 0.9987 if referred to the meter-millimeter standard. Yet, in the present understanding of this subject, purchasers would be little likely to press the question as to the exact basis upon which rests the manufacturer's statement of the conductivity of his product.

The value in dollars of a copper conductor, as will more fully appear later, is directly proportional to its conductivity. Hence, if in a sale of \$10,000 worth of cable this is paid for on the assumption that its conductivity is 1 per cent greater than it really is, the purchaser will become defrauded out of \$100.

As conductivity can be measured commercially to an accuracy better than 1/5 per cent, a clear understanding regarding the principles involved, and the standards referred to, should avoid all such unfair transactions. The money losses involved in a single transaction, resulting from a confused understanding of this subject, may amount to several hundreds of dollars.

In referring to the exact wording describing Matthiessen's standards it will be noted that "soft copper" is the material chosen for the standards. From this it might appear that it

is essential to compare the conductivities of copper and all other conductors with standards made of "soft copper." This is by no means the case. In reality, the standards are fully and sufficiently defined in the following terms:

The standard of conductivity is any material in the form of a rod of uniform cross-section, 1 m long, which weighs 1 gram and which has an ohmic resistance at 0° C. of 0.14173 international ohm. To this definition should be added the following explanatory clause:

As comparisons of the conductivities of conductors with the above standard are usually made at temperatures other than 0° C., the material of the concrete standard is best chosen when it has a temperature coefficient which is the same as that of the sample conductors which are to be compared with it. If this is done the relative and not the actual temperatures of the standard and samples need be known at the time of the comparison. The coefficients being alike, if the temperatures of the two conductors under comparison are maintained alike, the comparison may be made with precision without regard to the temperature value. That the concrete standard of conductivity should be copper is only a matter of convenience when copper samples are being measured.

When iron or aluminium samples are to be measured iron or aluminium standards are the more convenient. If a copper standard is used for getting the conductivity of some other material, and the measurement is made at 0° C., or at some other temperature, and the effect of the different coefficients allowed for, by the nature of the definition, a correct result for the conductivity would be obtained, but not conveniently.

The standard of conductivity may be defined also as follows:

The standard of conductivity is a round wire of any material, 1 m long, 1 mm in diameter, which has a resistance at 0° C. of 0.0203 international ohm.

The two above definitions are equivalent when the material selected in both cases has a density of 8.89. The material having the above resistance and density may be found in copper, but not necessarily in "soft copper."

The same remarks as above apply to the desirability of choosing a material for the concrete standard to use which has a temperature coefficient the same as that of the samples which are to be compared with it.

It is thus seen that the introduction into the definitions of Matthiessen's standards of the term "soft copper" should be considered useful as being merely descriptive of a material quite frequently suitable to use for embodying the standards in concrete form. With the introduction of iron, aluminium and bimetallic conductors, copper is often a very unsuitable material with which to make concrete standards of conductivity.

Relations Which Exist Between the General and Specific Properties of Conductors.

The relations between the conductivity and the general properties of conductors, which are useful to know for ascertaining their capacity for conveying electric power and their money value, may be found as follows:

It is first required to find an expression for the conductivity of any round, homogeneous conductor of uniform diameter when referred to the meter-millimeter standard.

The ohmic resistance of any conductor at temperature T and temperature coefficient θ' is, $r_T = r_0\theta'$, r_0 being its resistance at 0° C. If the conductor has a length L and is of uniform diameter D and of circular cross-section,

$$r_T = \frac{4kL\theta'}{\pi D^2}$$

k being an arbitrary constant.

If $T = 0$, $\theta' = 1$; and if $L = 1$, $D = 1$, then

$$\frac{1}{r_0} = \frac{\pi}{4k} = C_0,$$

which expresses the conductance of a round wire of unit length

and unit diameter at temperature 0° C. Then $k = \frac{\pi}{4 C_0}$

which value placed in the expression for r_T gives

$$C_0 = \frac{L\Theta'}{r_T D^2}$$

Similarly, for any other round conductor, of length l , diameter d , resistance R_t , at temperature t , and of temperature coefficient Θ , the conductance of unit length and unit diameter at 0° C. is:

$$C = \frac{l\Theta}{R_t d^2}$$

Conductivity being the ratio of the conductance of one conductor, called the sample, to the conductance of another conductor, called the standard, we have

$$C_s = \frac{C}{C_0} = \frac{l\Theta}{R_t d^2} \cdot \frac{r_T D^2}{L\Theta'} \quad (4)$$

In Matthiessen's meter-millimeter standard the conductance C_0 is taken as unit conductance when $L = 1$ m, $D = 1$ mm and $T = 0^\circ$ C., in which case $\Theta' = 1$. Substituting these values in (4) gives

$$C_s = \frac{l\Theta r_0}{R_t d^2} \quad (5)$$

(5) is an expression for the conductivity by the meter-milligram standard of any round wire l m in length of diameter d mm, of temperature coefficient Θ and of ohmic resistance R_t ohms at temperature t° C. When the standard is Matthiessen's standard r_0 is always equal to 0.0203 ohm. By definition $\Theta = \frac{R_t}{R_0}$, where R_0 is the ohmic resistance of the conductor at 0° C.

It is required, second, to find an expression for the conductivity of any conductor when referred to the meter-gram standard.

The mass of a length L of any conductor having a uniform cross-section S is $W = k'LS$, where k' is a constant. The ohmic resistance at temperature T of any conductor is

$$r_T' = \frac{kL\Theta'}{S}$$

where k is a constant and Θ' is the temperature coefficient. Placing the value of S obtained from the former expression in the latter gives

$$r_T' = \frac{k'kL^2\Theta'}{W} \quad (6)$$

If, in the above, $T = 0$, $\Theta' = 1$, and if $L = 1$ and $W = 1$, we have

$$r_0' = kk'$$

$$\frac{1}{r_0'} = \frac{1}{kk'} = C_0$$

which is the conductance of a conductor of unit length and unit mass at 0° C. Replace in (6) the value of kk' by its value $\frac{1}{C_0}$ and we obtain

$$C_0 = \frac{L^2\Theta'}{r_T'W}$$

Similarly for any other conductor of length l , mass w , resistance R_t at temperature t and temperature coefficient Θ , the conductance of unit length and unit mass at 0° C. is,

$$C = \frac{l\Theta}{R_t w}$$

As conductivity is the ratio of two conductances, we have

$$C_w = \frac{C}{C_0} = \frac{l\Theta}{R_t w} \cdot \frac{W r_T'}{L^2\Theta'} \quad (7)$$

In Matthiessen's meter-gram standard the conductance C_0 is taken as unit conductance, when $L = 1$ m, $W = 1$ gram and

$T = 0^\circ$ C., in which case $\Theta' = 1$. Substituting these values in (7) gives

$$C_w = \frac{l\Theta r_0'}{R_t w} \quad (8)$$

(8) is an expression for the conductivity by the meter-gram standard of any wire l meters in length, and of w grams mass, of temperature coefficient Θ , and of ohmic resistance R_t ohm at temperature t° C.

When the standard is Matthiessen's standard, r_0' is always equal to 0.14173 international ohm.

It should be noted that in (8) neither diameters nor densities appear.

(5) and (8) give two ways of expressing the conductivities of conductors, according as the lengths and diameters, or lengths and masses are given. In the first instance the meter-millimeter standard is referred to, and in the second instance the meter-gram standard is referred to.

The conductivity being expressed by (8), the equivalent conductivity, as expressed by (5), can only be given when the density of the material is known.

To connect the expressions (5) and (8) write,

$$w = \frac{\pi d^2 l \delta}{4}$$

where δ is the density of the material, and the conductor is assumed to be of circular cross-section and of diameter d . Putting this value of w in (8) gives

$$C_w = \frac{4 l \Theta r_0'}{\pi d^2 R_t \delta} \quad (9)$$

and taking the ratio of (9) to (5) we obtain

$$C_w = \frac{4 r_0'}{\pi r_0 \delta} C_s \quad (10)$$

(10) gives the relation of the conductivities of the same conductor when referred to the meter-gram standard and when referred to the meter-millimeter standard.

Replacing in (10) the values in Matthiessen's standards for r_0' and r_0 , which are, respectively, 0.14173 and 0.0203, we have the expression,

$$\frac{C_w}{C_s} = \frac{8.89}{\delta} \quad (11)$$

(11) is very useful for connecting the conductivity when given in terms of the meter-gram standard with the conductivity in terms of the meter-millimeter standard, and vice versa, when the density of the material can be ascertained. Thus, if the conductivity of aluminium is given as 0.615 in terms of the meter-millimeter standard, and its density is taken as 2.7, then its conductivity in terms of the meter-gram standard is

$$C_w = \frac{8.89}{2.7} \times 0.615 = 2.025.$$

Bimetallic Conductors.

The relations which exist between the general and specific properties of bimetallic conductors are important to know in order to be able to estimate their money value and to make certain calculations respecting them.

Let Fig. 1 represent in section a bimetallic conductor, made up of a central core V and an external covering U .

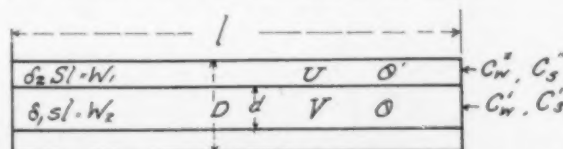


FIG. 1.—BIMETALLIC CONDUCTOR.

Let Θ' , δ_s , S , l , W_1 designate, respectively, the temperature coefficient, density, cross-sectional area, length and mass of the envelope U .

Let Θ , δ_v , S_v , l , W_2 designate the corresponding quantities for the core V . Also, let Θ'' , δ_t , S_t , l , W designate, respectively,

the corresponding quantities for the bimetallic conductor, considered as a whole and which will be called Q . Let R_t be the ohmic resistance at temperature t of the length l of the bimetallic conductor. Put

C_s	=	conductivity of Q	by meter-millimeter standard	
C_s'	=	"	"	"
C_s''	=	"	"	"
C_w	=	"	"	"
C_w'	=	"	"	"
C_w''	=	"	"	"

By (5)

$$C_s = \frac{l r_0 \theta''}{R_t D^2} \quad (12)$$

where D is the diameter of the bimetallic conductor assumed to have a circular cross-section. Since the cross-section is,

$$S_t = \frac{\pi D^2}{4}, \quad C_s = \frac{\pi l r_0 \theta''}{4 R_t S_t} \quad (13)$$

The relation (13) holds if the bimetallic conductor is not of circular cross-section. By the principle of (8)

$$C_w = \frac{F r_0' \theta''}{R_t W} \quad (14)$$

As $W = S_t \delta_t l$, we have also

$$C_w = \frac{l r_0' \theta''}{R_t S_t \delta_t} \quad (15)$$

By (11)

$$C_s = \frac{\delta_t}{8.89} C_w \quad (16)$$

(12) and (13) are two expressions for the conductivity of the bimetallic conductor by the meter-millimeter standard; (14) and (15) are two expressions for the conductivity of the bimetallic conductor by the meter-gram standard, and (16) is an expression which connects the conductivity in terms of the one standard with the conductivity in terms of the other standard.

The conductivities, the densities, and the ratio of the cross-sections or weights of the component materials of the bimetallic conductor may be known, and it may be required, then, to calculate the conductivities of the compound conductor. The necessary relations for making these and other useful calculations may be obtained as follows:

Call r_t' the ohmic resistance of U and r_t the ohmic resistance of V both at temperature t . Then

$$\frac{1}{R_t} = \frac{1}{r_t'} + \frac{1}{r_t} \quad (17)$$

From (13)

$$\frac{1}{R_t} = C_s \frac{4 S_t}{\pi l r_0 \theta''}$$

and by the same principle

$$\frac{1}{r_t'} = C_s'' \frac{4 S}{\pi l r_0 \theta'}$$

and

$$\frac{1}{r_t} = C_s' \frac{4 s}{\pi l r_0 \theta}$$

Placing these values in (17) gives

$$C_s = \frac{\theta''}{\theta \theta'} \left(\frac{S C_s'' \theta + s C_s' \theta'}{S_t} \right) \quad (19)$$

Since (19) is true for any temperature, it is true for the temperature of 0°C ., at which temperature all coefficients are defined as equal to unity. Thus in (19) we can put θ , θ' and θ'' equal to 1 when we have,

$$C_s = \frac{S C_s'' + s C_s'}{S_t} \quad (20)$$

It may be added that $S_t = S + s$.

If we equate (19) to (13), we get

$$R_t = \frac{\pi l r_0 \theta \theta'}{4 (S C_s'' \theta + s C_s' \theta')} \quad (21)$$

and if we equate (20) to (13), we get

$$R_t = \frac{\pi l r_0 \theta''}{4 (S C_s'' + s C_s')} \quad (22)$$

Again, we have from (14)

$$\frac{1}{R_t} = \frac{W C_w}{l r_0' \theta''}$$

and by the same principle

$$\frac{1}{r_t'} = \frac{W_1 C_w''}{l r_0' \theta'}$$

and

$$\frac{1}{r_t} = \frac{W_2 C_w'}{l r_0' \theta}$$

whence by (17)

$$C_w = \frac{\theta''}{\theta \theta'} \left(\frac{\theta W_1 C_w'' + \theta' W_2 C_w'}{W} \right) \quad (23)$$

By the same reasoning, whereby (19) changes to (20), we have

$$C_w = \frac{W_1 C_w'' + W_2 C_w'}{W} \quad (24)$$

By equating (14), first to (23) and second, to (24) we get

$$R_t = \frac{\theta \theta' F r_0'}{\theta C_w'' W_1 + \theta' C_w' W_2} \quad (25)$$

and

$$R_t = \frac{F r_0' \theta''}{C_w'' W_1 + C_w' W_2} \quad (26)$$

In the expressions (21) and (25) the ohmic resistance at any temperature t of the bimetallic conductor may be calculated, if we know the temperature coefficients of each of the component materials, while in expressions (22) and (26) the temperature coefficient must be known of the compound conductor. Since to obtain temperature coefficients it is necessary only to measure the resistances at different temperatures with precision relatively, the coefficient, θ'' , may be obtained easily and without the use of accurate standards.

Again, if in (16) C_w is replaced by its value in (24) and W_1 by its value $\delta_1 S_1$, W_2 by its value $\delta_2 s$, and W by its value $\delta_t S_t$ or $\delta_t (S + s) l$, we obtain

$$C_s = \frac{S \delta_1 C_w'' + s \delta_2 C_w'}{8.89 (S + s)} \quad (27)$$

Thus, if the conductivities of the component materials, in terms of the meter-gram standard are known, also, the densities of the component materials and the cross-section of each, the conductivity of the bimetallic conductor, by the meter-millimeter standard may be calculated by (27). It is necessary only to know the ratio of $\frac{S}{s}$, which, if we call this ratio q , gives in place of (27)

$$C_s = \frac{q \delta_1 C_w'' + \delta_2 C_w'}{8.89 (q + 1)} \quad (28)$$

The relations given in expressions (12) to (28) together with others which may be derived easily from them are sufficient for calculating resistances, conductances or conductivities of bimetallic conductors, expressed in either the meter-millimeter or the meter-gram standard, if the necessary data are given.

The Money Value of Conductors.

If the relative money values of the many types of electric conductors is to be ascertained, it is necessary to express the values of the different conductors in terms of one common unit of comparison. If one company gives the net price of 100 lb. of No. 8 copper, and another the net price of 1000 ft.

of No. 8 copper, no precise comparison is possible between these prices as they are listed. In the heterogeneous manner in which conductors are mostly listed it is generally puzzling and sometimes impossible (for sufficient data is not given) to compare prices accurately.

A conductor has value as a conveyor of electric power. It may possess additional value due to its tensile strength, lasting qualities, insulation, etc. But if the relative power conveying value of conductors is taken as a first uniform basis for ascertaining their relative money value, then, this having been done, it is easy to add or subtract a certain per cent value for other qualities which they may possess. If the electric power-conveying capacity, or what is the same thing, the conductance, per 1000 ft. or per mile, were taken as the one common basis for making a first comparison of the relative money value of conductors much uncertainty and confusion now existing would be ended. However, as the conductance of a conductor, or the reciprocal of its resistance, changes with the temperature, it does not make the best basis for the relative valuation of conductors of various kinds. We have a better basis in the product of the weight per unit of length by the conductivity in terms of the meter-gram standard. To show this, write,

$$\$ = \frac{K}{R_t} \quad (30)$$

where \$ is the value in dollars of any conductor which has a resistance R_t at temperature t , and K is a constant.

From (8) we derive a value for $\frac{1}{R}$, which placed in (30) gives

$$\$ = \frac{KWC_w}{F r_o \Theta} \quad (31)$$

As $\frac{K}{F r_o}$ is a constant, call it A and write

$$\$ = A \frac{WC_w}{\Theta} \quad (32)$$

From this expression it is evident that the money value to the user of a given length of an electric conductor, when considered only as a conveyor of electric power, will increase directly as its weight and its conductivity, based upon the meter-gram standard. Its value will decrease as its temperature coefficient is greater. The value of the temperature coefficient, at a particular temperature, will vary but little for different conductors made of pure metals. The magnitude of the constant A will depend upon several factors, such as the units of length and weight chosen.

Expression (32) gives, however, a means of reducing to a common basis of comparison the value to the user of a given length of any conductor. We may take as the standard of value the market price of a given length and weight of copper. We can easily express then the value to the user of any other conductor, as one of aluminium, or bimetallic conductors, as compared with this copper conductor. The value to the purchaser will be the value of the conductor as a conveyor of electric power as compared with the value of a specified copper conductor. If the conductor considered has value additional to its power conveying capacity, such as superior tensile strength, then this must be separately considered and allowed for. But when the relative worth of a number of different types of conductors have to be considered, they should first be set off against one another in respect to their value as conveyors of electric power, and only after this has been done should claims to additional worth of various conductors be considered.

If we put as the value of a given length of copper conductor of weight W_1 and temperature coefficient Θ_1 , and conductivity C_w

$$\$_1 = A \frac{W_1 C_w'}{\Theta_1} \quad (33)$$

then comparing (32) and (33)

$$\$ = \frac{\$_1}{W_1 C_w'} W C_w \frac{\Theta_1}{\Theta}$$

For all pure metals, the error for commercial purposes will be negligible if Θ_1 is taken equal to Θ and we may also with advantage consider $C_w' = 1$, then

$$\$ = \frac{\$_1}{W_1} W C_w \quad (34)$$

In (34) if $\$_1$ is the market price in dollars of a given length of 100 per cent conductivity copper which weighs W_1 lb., then \$ expresses what W lb. of any other conductor of conductivity C_w is worth as compared with the above copper conductor. It must not be forgotten, of course, that (34) relates only to the relative power conveying value of the conductors.

It is concluded that the product, weight per unit length by conductivity on the metergram standard is the most satisfactory basis for comparing the relative worth of various electric conductors as conveyors of electric power.

In (30) we might have replaced the value of $\frac{1}{R_t}$ by its value derived from (5). Calling also S the cross-section of the conductor, $d^2 = \frac{4S}{\pi}$ and we derive finally

$$\$ = \frac{4K}{\pi l r_o} \frac{SC_s}{\Theta}$$

As $\frac{4K}{\pi l r_o}$ is a constant, call it B and write

$$\$ = B \frac{SC_s}{\Theta} \quad (35)$$

Similarly for another conductor write

$$\$_n = B \frac{S_n C_s'}{\Theta_1} \quad (36)$$

If it is assumed that the value (35) is compared with the value (36), the temperature and the length of the conductors being alike in both cases, also that $\Theta = \Theta_1$, and $C_s' = 1$, then we have an expression analogous to (34), namely,

$$\$ = \frac{\$_n}{S_1} S C_s \quad (37)$$

In (37) if $\$_n$ is the market price in dollars of a given length of 100 per cent, conductivity (by the meter-millimeter standard) copper which has a cross-section of S_1 circular mils, then \$ expresses what any other conductor, of the same length, is worth when its cross-section is S circular mils and its conductivity (by the meter-millimeter standard) is C_s .

It would not be unreasonable to use (37) instead of (34) to express the relative values of different conductors in respect to their electric power conveying capacities, but as the product WC_w can be more easily determined than the product SC_s , the expression (34) is to be preferred. This is especially true in the case of stranded conductors where S cannot be determined precisely.

In arriving then at the relative money values of different electric conductors it becomes necessary to determine their conductivities on the basis of Matthiessen's metergram standard. We shall very briefly give the method of doing this, which theory and an extended experience shows to be the most rapid and the most accurate.

The Measurement of Conductivity.

The commercial measurement of conductivity involves the comparison of the unknown resistance of a low-resistance wire having a large temperature coefficient with the known resistance of a wire having the same temperature coefficient.

If the standard and sample wires are kept at the same temperature, and both have the same coefficient, the comparison may be made accurately without the actual temperature

being known. The apparatus best suited for the comparison of low resistances is the Kelvin Bridge, and it is this form of bridge, fitted with special reading scales, invented by Mr. Wm. Hoopes, which most generally is used for conductivity measurements.

The essential principles of the method are exhibited in the diagrams Figs. 2 and 3, the two arrangements shown being electrically identical.

It is required to measure the low resistance of a rod X in terms of the known resistance of a standard P . X is connected in series with P through the medium of a heavy copper connection E . r , p and r_1 and p_1 are ratio coils of large resistance as compared with X and P .

From the arrangement as exhibited in Fig. 2 it is evident that, if E were to have zero resistance and b and d came together,

that $\frac{p}{r} = \frac{P}{X}$ or $X = \frac{r}{p} P$, for a galvanometer balance.

Theory shows that if the resistance of the yoke E is not negligible, then

$$\frac{P}{X} = \frac{p}{r} = \frac{p_1}{r_1}. \text{ Provided } \frac{p}{r} = \frac{p_1}{r_1},$$

as above, $X = \frac{r}{p} P$.

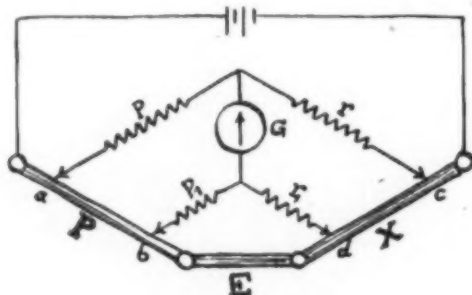


FIG. 2.—KELVIN BRIDGE.

In practice r is made equal to p so $X = P$ for a balance.

Referring to Fig. 2, suppose that X is a rod of copper having a cross-section S . Suppose the scale I to have 100 equal divisions of arbitrary length between the points c and d . The resistance and its reciprocal, the conductance, of the rod X will depend upon the purity and the physical condition in regard to hardness, temperature, etc., of the copper of which it is made.

Now suppose that P is also a rod of copper having a uniform, but not necessarily known, cross-section. Suppose the points a and b are separated until they include a length of the rod P which will have the same resistance as the resistance of the rod X of cross-section S , of 100 per cent conductivity, and of length equal to 100 divisions of scale I . This being done, the bridge will be balanced. Now, if no change is made in P or in the position of the contacts a and b , and we substitute

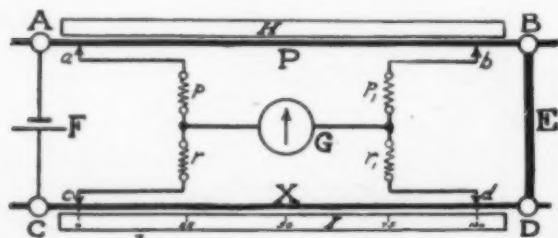


FIG. 3.—KELVIN BRIDGE.

for X another rod X' of the same cross-section but of less conductivity, it will then be necessary, in order to balance the bridge, to move the contact d towards the zero mark of scale I . Suppose the second rod X' has twice the resistance of X , or half the conductivity, then d will have to be moved for obtain-

ing a balance half way down the scale I ; that is, to the 50 division mark. Hence, in this case the 50 division mark indicates that rod X' has 50 per cent conductivity according to a standard based on cross-section.

Again, suppose we substitute for the rod X a rod X_1 which has 100 per cent conductivity, but twice the cross-section of rod X . In order to obtain a balance it will be necessary now

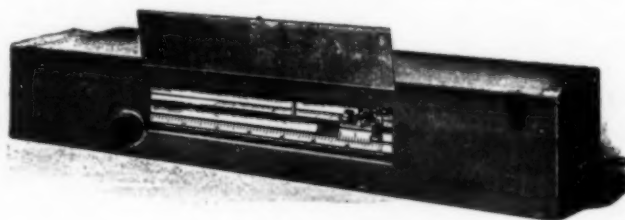


FIG. 4.—BRIDGE ENCLOSED.

to have the distance between a and b one-half what it was before. Then set b at the middle point of scale H . If now we substitute for X_1 a rod X_1' having the same dimensions, but of a lower conductivity than X_1 , a balance will be obtained by moving d toward the zero mark of scale I and the reading of the scale will, as in the former case, give the per cent conductivity of X_1' , which has twice the cross-section of the original rod X . Thus we may find a series of positions on the scale H corresponding to rods to be tested of various diameters or cross-sections.

Having a rod to test of a particular diameter, the slider b is set to a division on scale H corresponding to that particular diameter, then the reading on scale I gives directly, a balance being obtained, the per cent conductivity of the sample being tested.

The Kelvin bridge, fitted with the Hoopes's scales, as above described, gives the conductivity in terms of the meter-millimeter standard. As this bridge is actually constructed by its makers at the present time, the standard scale H , Fig. 2, is laid off in weights instead of diameters, and the bridge readings are then given on the scale I in per cent conductivities based upon Matthiessen's meter-gram standard. The bridge

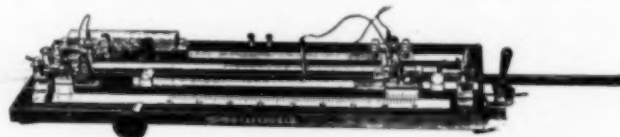


FIG. 5.—GENERAL VIEW OF BRIDGE.

gives by direct readings the values designated in this article by the symbol C_w , multiplied by 100.

In Figs. 4 and 5 are given views of Hoopes's conductivity bridge, in and out of its enclosing case. In practice, it is always used in its case, which is lined on the inside with sheet metal to insure equality of temperature throughout its interior. The bridge measures the conductivities of wires from No. 0000 B. & S. to No. 18 B. & S. gage.

It may be supplied with different standards to take care of wires of different sizes, and various kinds. One standard covers a range of three wire sizes, B. & S. gage. The standard wires are made of the same material as the samples to be measured to insure an equality between the temperature coefficients of standard and samples.

An active person in a working day can measure conductivities to a precision of better than 1/5 per cent of 150 sample wires. The measurement involves these processes: Cutting off to a standard length and weighing the samples, setting the index on the standard scale to the weight of the sample to be measured, and balancing the bridge. When this balance is obtained the vernier scale reads directly the per cent conductivity to 1/10 per cent, or better. More detailed descrip-

tions of this bridge and its accessories may be obtained from its makers, the Leeds & Northrup Company, Philadelphia, Pa.

Appendix.

In the following is given a summary of the more useful of the formulas which have been deduced. The formulas are lettered for ready reference, but the numbers, in parentheses following the formulas, are the same numbers given to them in the text.

The same symbols have the same meanings throughout, and are the same as used in deducing the formulas.

The numerical values given to constants assume that Matthiessen's metergram and meter-millimeter standards are referred to, where $r_0' = 0.14173$ and $r_0 = 0.0203$.

The meanings of the symbols are restated for readiness of reference, and a numerical example is given under each case to aid to a clear interpretation.

In each formula where the conductivity appears, this is treated, in the example, as the unknown quantity. It is evident, however, that the formulas may be made to express the value of any single unknown quantity which they contain, when the remaining quantities in the formulas are given.

$$(a) \quad C_s = \frac{0.0203 l \theta}{R l d^2} \quad (5)$$

or

$$(b) \quad C_s = \frac{0.01594 l \theta}{R l S}$$

C_s = conductivity by meter-millimeter standard, 100 C_s = per cent conductivity by same standard.

l = length in meters.

d = diameter of a round conductor in millimeters.

S = cross-section of a conductor of uniform cross-section measured in square millimeters. If the cross-section is called V , and is in circular mils, write

$$S = \frac{V}{1973.52}$$

R_t = resistance in ohms of length l m at a temperature t degrees centigrade.

θ = the temperature coefficient of the conductor considered, when this conductor is at a temperature of t degrees centigrade. The value of this coefficient will be different for conductors of different materials. It is nearly the same for the pure metals. Its value for copper can be found from a table given in the proceedings of the A. I. E. E., Vol. X, January, 1903, to December, 1903, page 25. Also this table may be found copied on page 18 of "Wire in Electrical Construction," published by John A. Roebling's Sons Company, Trenton, N. J.

For 20 deg. C. the value of θ is given as 1.07968 for copper. Call it 1.08.

$$(c) \quad C_s = \frac{31.457 l \theta}{R l V}$$

V = cross-section of conductor expressed in circular mils.

$$(d) \quad C_w = \frac{0.14173 l \theta}{R l W} \quad (8)$$

W = mass of l m expressed in grams.

C_w = conductivity by Matthiessen's metergram standard.

$$(e) \quad C_w = \frac{8.89}{\delta} C_s \quad (11)$$

C_s = conductivity by Matthiessen's meter-millimeter standard.

δ = density of the material of the conductor.

$$(f) \quad C_s = \frac{S C_s'' + s C_s'}{S + s} \quad (20)$$

S = cross-section of covering and s = cross-section of core of bimetallic conductor.

S and s may be expressed as multiples of any unit, provided the same unit is chosen for each.

C_s'' = conductivity of covering and

C_s' = conductivity of core, both by the meter-millimeter standard.

$$(g) \quad C_w = \frac{W_1 C_w'' + W_2 C_w'}{W}$$

W = the total weight of a given length of a bimetallic conductor.

W_1 = the weight of the covering and

W_2 = the weight of the core. These weights may be expressed in any units, provided the same units are used for all three.

C_w'' = conductivity of covering and

C_w' = conductivity of core; both by the meter-gram standard.

$$(h) \quad C_s = \frac{q \delta_s C_w'' + \delta_1 C_w'}{8.89 (q + 1)} \quad (28)$$

q = ratio of the cross-section of the covering to the cross-section of the core.

δ_s = density of material of covering.

δ_1 = density of material of core.

$$(i) \quad R_t = \frac{0.01594 l \theta''}{S C_s'' + s C_s'} \quad \text{See (22)}$$

θ'' = temperature coefficient of the bimetallic conductor.

R_t = ohmic resistance in ohms at t degree centigrade of l m of the bimetallic conductor

$$(j) \quad R_t = \frac{31.457 l \theta''}{v_1 C_s'' + v_2 C_s'}$$

V_1 = cross-section of covering of bimetallic conductor expressed in circular mils and

v_2 = cross-section of core expressed in circular mils.

$$(k) \quad R_t = \frac{0.14173 l \theta''}{C_w'' W_1 + C_w' W_2} \quad (26)$$

$$(l) \quad \$ = \frac{\$_1}{W_1} W C_w \quad (34)$$

$\$_1$ = the value in dollars of a weight, W_1 , of a pure copper conductor of a given length.

W = weight in same units as W_1 of the same length of some other conductor whose electric power conveying value as compared with pure copper is sought.

$\$$ = value in dollars.

$$(m) \quad \$ = \frac{\$''}{S_1} S C_s \quad (37)$$

$\$_1$ = the value in dollars of a given length of pure copper conductor having a cross-section S_1 .

S = Cross-section of same length of conductor whose value is sought.

Example (1).

A copper wire is 2 mm in diameter and 4 m long, and has a resistance at 20 deg. C. of 0.0223 ohm. By (a) its conductivity is by Matthiessen's meter-millimeter standard:

$$C_s = \frac{0.0203 \times 4 \times 1.08}{0.0223 \times 4} = 0.9876$$

or 98.76 per cent conductivity.

Example (2).

An aluminium wire is 1 sq. mm in cross-section and 2 m long, and has a resistance at 20 deg. C. of 0.05644 ohm. Calling its temperature coefficient at 20 deg. C., $\theta = 1.08$, by (b) its conductivity is:

$$C_s = \frac{0.01594 \times 2 \times 1.08}{0.05644 \times 1} = 0.61$$

or 61 per cent conductivity.

Example (3).

The cross-section of the wire under example (2) is given in circular mils as 1973.52, then by (c)

$$C_s = \frac{31.457 \times 2 \times 1.08}{0.05644 \times 1973.52} = 0.61$$

or 61 per cent conductivity.

Example (4).

An aluminium wire is 2 m long and weighs 50 grams. Its resistance at 0 deg. C. is 0.00585 ohms. Then $\Theta = 1$ and by (d) its conductivity by Matthiessen's meter-gram standard is:

$$C_w = \frac{0.14173 \times 4 \times 1}{0.00585 \times 50} = 2.03 \text{ or } 203 \text{ per cent.}$$

Example (5).

The density of aluminium is 2.7 and its conductivity is 0.615 by the meter-millimeter standard, then by (e) its conductivity by the meter-gram standard is:

$$C_w = \frac{8.89}{2.7} \times 0.615 = 2.0249 \text{ or } 202.49 \text{ per cent.}$$

Example (6).

A wire is made up of a steel core, having a conductivity by the meter-millimeter standard of 0.16 and an aluminium covering having a conductivity of 0.61. The cross-section of the core is 2000 circular mils, and that of the covering is 4000 circular mils. Then by (f), the conductivity of the duplex wire is:

$$C_s = \frac{4000 \times 0.61 + 2000 \times 0.16}{4000 + 2000} = 0.46 \text{ or } 46 \text{ per cent.}$$

Example (7).

A conductor has a steel core of conductivity by the meter-gram standard of 0.20, and an aluminium covering of conductivity by the meter-gram standard of 2. The steel core of a given length of the conductor weighs 10 lb., and the aluminium covering 8 lb. Then by (g) the conductivity of the conductor is:

$$C_w = \frac{8 \times 2 + 10 \times 0.2}{18} = 1, \text{ or } 100 \text{ per cent.}$$

Example (8).

In the conductor under example (7) the density δ_1 of the steel core is 7, and the density of δ_2 of the aluminium covering is 2.7. The ratio of the cross-section of the covering to that of the core would be, for the core chosen, $q = \frac{S}{s} = \frac{W_1 \delta_1}{W_2 \delta_2} = \frac{8 \times 7}{10 \times 2.7} = 2.074$. Taking as in example (7) C_w' for the core, = 0.2, and C_w'' for the covering = 2, then by (h) the conductivity of the conductor by the meter-millimeter standard is:

$$C_s = \frac{2.074 \times 2.7 \times 2 + 7 \times 0.2}{8.89 \times (2.074 + 1)} = 0.4610$$

or 46.1 per cent conductivity by the meter-millimeter standard.

Example (9).

A bimetallic conductor 304.8 m long has a steel core 16.72 sq. mm cross-section and a copper covering 25.59 sq. mm cross-section. The conductivity by the meter-millimeter standard of the core is 0.16 and of the covering 1.00. If at 20 deg. C. the coefficient Θ'' is found to equal 1.09, then by (i) the resistance of this conductor at 20 deg. C. is:

$$R_w = \frac{0.01594 \times 304.8 \times 1.09}{25.59 \times 1 + 16.72 \times 0.16} = 0.1873 \frac{1}{2} \text{ ohms.}$$

If the cross-section of the covering, called C' , and of the core, called C , are given in circular mils, then to calculate the resistance the formula (j) may be used to better advantage.

Example (10).

A bimetallic conductor is 1000 m long. The weight W_1 of its steel core is 180,000 grams, and the weight of its aluminium covering is 59,100 grams. The conductivity of the core by the meter-gram standard is 0.2 and of the covering 2.03. At 20 deg. C. its temperature coefficient is found to be 1.09. Then by (k) its resistance is:

$$R_w = \frac{0.14173 \times 1000^2 \times 1.09}{2.03 \times 59,100 + 0.2 \times 180,000} = 0.9903 \text{ ohms.}$$

Example (11).

Suppose that 100 lb. of a certain length of 100 per cent con-

ductivity copper is worth \$20, then by (1) 250 lb. of the same length of aluminium wire of 2.03 or 203 per cent conductivity, by the meter-gram standard, is worth:

$$\$ = \frac{20 \times 250 \times 2.03}{100} = \$101.50.$$

This is the value of the aluminium as compared with the copper wire when considered only as a conveyor of electric power. Equal weights of the same length of aluminium and copper have values, as conveyors of electric power, in the ratio of about 2 to 1.

Example (12).

Suppose that 100 ft. of copper conductor of 105,625 circ. mils is worth \$64, then by (m) 1000 ft. of aluminium conductor of conductivity 0.6, by the meter-millimeter standard, and 133,225 circ. mils is worth:

$$\$ = \frac{64}{105,625} \times 133,225 \times 0.6 = \$48.44.$$

Equal cross-sections of the same lengths of aluminium and copper have values as conveyors of electric power in the ratio of about 6 to 10.

The Combustion of Producer Gas.

BY DR. OSKAR NAGEL.

High efficiency of combustion depends on thoroughness of the gas-air mixture, and on preheating the air. In order to obtain a temperature of bright red incandescence it is imperative to preheat the air for combustion by exposing it to the temperature of the hot products of combustion passing to the stack.

A good many devices for mixing the gas and air consist simply of two concentric pipes, one for air and one for gas.

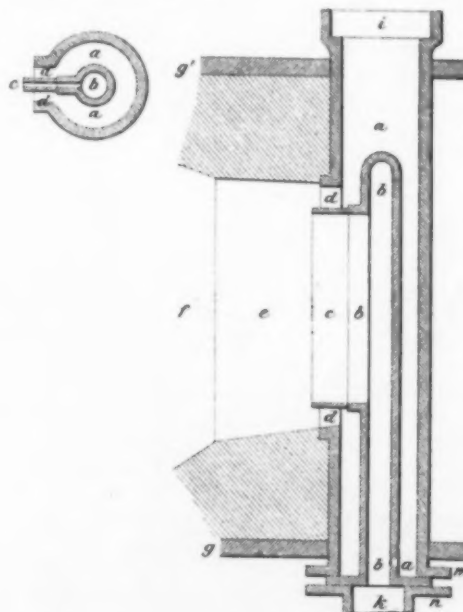


FIG. 1.—MIXING DEVICE FOR GAS AND AIR.

In Fig. 1 we have a gas pipe a , an air pipe b , a collar c ; d is the opening of the gas pipe, e the flue, f the hearth, g the front plate of the furnace, g' the back plate, i the connection to the gas line, k the connection to the air line. b can be turned around its axis between the flanges m and n in order to give the flame the desired angle toward the hearth.

For a downward direction of the flame, the burner shown in Fig. 2 is very practicable; b is the air, a is the gas pipe.

The manner in which gas and air meet is of great importance for proper combustion. By a suitable arrangement of the gas and air channels a long or short flame can be produced. If air and gas are brought together at right angles (Fig. 3) a rapid,

concentrated combustion is effected. For every gas channel there is a corresponding air channel.

The arrangement shown in Fig. 4 effects a more rapid combustion as the gas rises toward the horizontal air current. The air, on account of its higher specific gravity, rapidly mixes with the gas.

If the currents of gas and air are carried parallel into the furnace, the combination of gas and air is gradual and a long flame is the result (Fig. 5). The flame is shortened if gas and air enter at an angle (Fig. 6).

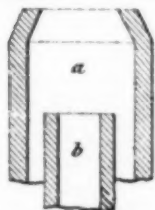
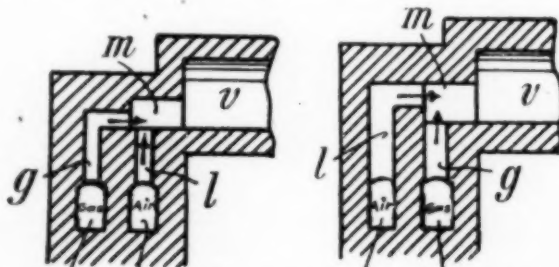


FIG. 2.—MIXING OF GAS AND AIR.

Another method is shown in Fig. 7. The air enters through slit *l* and the gas is blown through, drawing along a sufficient amount of air from *l*. Gas and air meet in *m* and are burned in *v*.

The small furnaces used in the metal industries for tempering and annealing are still generally heated by illuminating gas or other rich gases. However, they can also be used for producer gas, if the gas and air have a sufficiently high pressure. The temperature obtained increases with the pressure.

In order to obtain the highest economy in gas-fired furnaces where high temperatures are to be reached, successful use may be made of the principle of regeneration, i.e., of storing the waste heat in regenerators (heat storers consisting of chambers filled with firebrick checker work). It is evident that the gas and air currents must travel in a direction opposite to that of



FIGS. 3 AND 4.—MIXING DEVICES FOR GAS AND AIR.

the products of combustion, if it is desired to transfer the sensible heat of the waste gases to the incoming gas and air. It follows that a regenerative furnace consists of two symmetrical parts, the axis of each going through reversing mechanism. Each part consists of an air regenerator and a gas regenerator or of an air regenerator only.

The two air regenerators are connected by means of a reversing valve. Also the two gas regenerators.

Fig. 8 shows the plan of a regenerator system; *h h* are the air, *h' h'* the gas regenerators, *a* the air, *a'* the gas-reversing valve, *c* the gas main, *b* the opening for the air for combustion, *a* the stack. At the position of the valves shown air and gas travel to the left, combine in the flue above *e*, pass as flame over the hearth through the right-side regenerators and valves and leave through *d*.

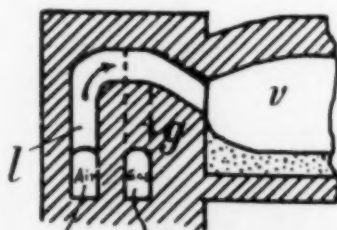


FIG. 5.—MIXING DEVICE FOR GAS AND AIR.

Fig. 10 the same type of furnace after its transformation to gas firing. First of all, we note the more convenient way of charging the fuel to the gas-fired furnace, the fuel being charged through a door *t* on top, while with direct firing the fuel has to be thrown in through the front door. The grate *r* carries in the first case a low bed of fuel and complete com-

busion to carbon dioxide takes place. In the second construction (gas fire) the grate carries a high bed of fuel and the effective gas is carbon monoxide.

In the first type of furnace the products of complete combustion heat the hearth and escape through the stack, in the second type the complete combustion takes place at the hearth, just where it is wanted, and the heat stored in the firebrick work below the hearth is utilized for pre-heating the air for combustion, passing through a flue *l* provided for this purpose. This comparison shows the greater convenience and higher economy of gas firing.

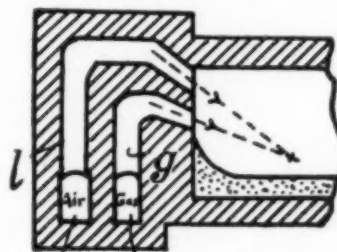


FIG. 6.—MIXING DEVICE FOR GAS AND AIR.

Electric Hardening Furnaces.

On page 95 of our February issue we described in detail the construction of the hardening furnace with electrically heated salt bath, built by the General Electric Company of this country. Former descriptions of the same type of furnace, as built in Europe, were given in our Vol. IV, page 667; Vol. V, page 428, and Vol. VI, page 419.

A great many details of the working of this furnace are given in a recent Faraday Society paper of Messrs. E. SABERSKY and E. ADLER.

The salt employed is usually a mixture of KCl and BaCl_2 , and Table I shows some of the materials used for different requirements. Current is transmitted to the bath by two electrodes made of Swedish ingot iron, which is characterized by a particularly low percentage of carbon, possessing a melting point of 1500 deg. C. to 1600 deg. C.

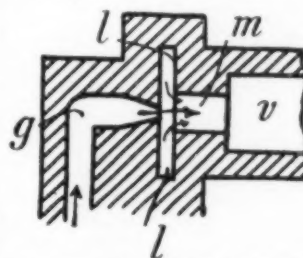


FIG. 7.—MIXING DEVICE FOR GAS AND AIR.

Process.	Temperature.	Salts.
Tempering steel	200-580°C	$\text{NaNO}_3 + \text{KNO}_3$
Annealing copper alloys, etc.	650-900	NaCl or $\text{NaCl} + \text{KCl}$
Hardening carbon steels	750-1,100	$\text{KCl} + \text{BaCl}_2$
Hardening compound steels	1,050-1,350	BaCl_2
For special purposes requiring higher temperatures	1,500-1,600	CaF_2 or MgF_2

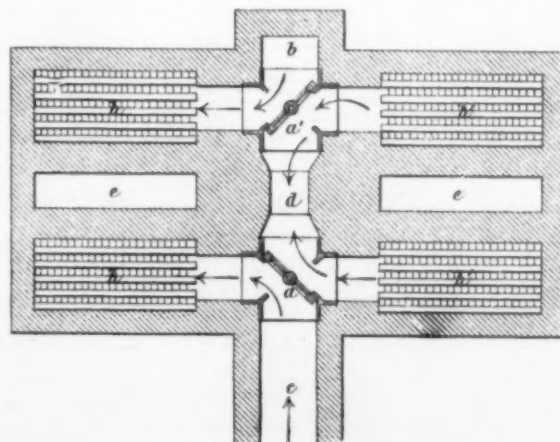


FIG. 8.—REGENERATIVE SYSTEM.

When all the salts have become melted, the voltage necessary for maintaining the temperature is about 5 to 30 volts, while the heating-up voltage reaches about 70 volts. Such low volt-

ages are not available from an ordinary supply systems and consequently a transformer has to be used.

It is arranged for any primary voltage up to 550 volts, while the maximum secondary voltage is about 70 volts. The secondary current is between 700 and 2800 amp in the different sizes of numerous furnaces.

The heat developed, and thus the temperature of the bath, are dependent on the voltage impressed on the furnace. If it is

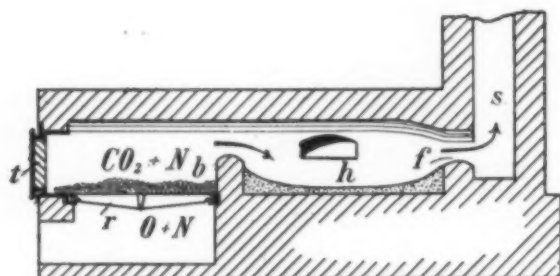


FIG. 9.—DIRECT-FIRED FURNACE.

desired to alter the temperature this can, therefore, be done by a variation of the voltage. The fact that a transformer is necessary makes the voltage control comparatively simple. Tappings are brought out from the primary winding of the transformer to a regulator switch, and thus the number of primary turns—that is, the ratio of the transformer—can be altered at will. This method of control, together with a tapping on the secondary side, gives 50 steps, which means 50 different temperatures, these being sufficient for most purposes. If as, for instance, in laboratory work, a still finer regulation is desired, a resistance is inserted in the primary which makes it possible to obtain up to, say, 500 steps. If the installation comprises a converter or a separate generator, a very effective means of voltage control is obtained by altering the exciter voltage.

An important part of the hardening installation is the pyrometer. For the temperatures in question the thermocouple type of pyrometer seems to give the most reliable results, but it has to be employed in a form suitable under the trying influence of the salt bath. In its latest shape it forms an angle,

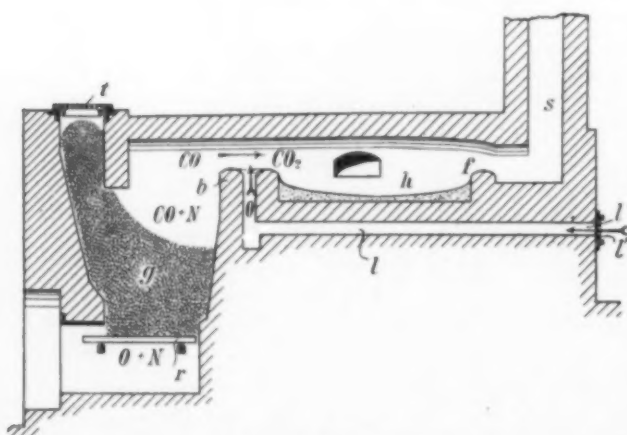


FIG. 10.—GAS-FIRED FURNACE.

the upper limb of which carries the terminals, these being thus outside of the destructive influence of the heat.

The thermocouple used is platinum, platinum-rhodium, protected by different protecting sheaths of Marquardt composition and steel. A steel cylinder protects the most sensitive part; that is, the one projecting from the bath. This part gets white hot, and unless protected against the oxidizing influence of the air would show signs of wear.

The e.m.f. of the thermocouple is read on a dead-beat moving-coil galvanometer, calibrated both in millivolts and degrees C., and reading up to 1600° C.

For ordinary purposes, and if the voltage remains fairly steady, the ammeter reading gives sufficient indication as to the temperature, and the pyrometer will only be used occasionally for checking.

On the basis of Robert Austin's well-known phase diagram the authors then consider the process of hardening. It consists essentially of two stages: First, the steel is heated up to a temperature corresponding to the state of martensite, i.e., a solid solution of carbon in a solvent of ferrite iron. The higher the temperature, the more evenly will the mixture be distributed, but if a certain temperature is exceeded the steel will, of course, be damaged.

The second stage is the fixation of the martensitic state by rapid cooling down. If the steel cools slowly, pearlite is formed and the steel becomes soft. But by means of rapid cooling we "freeze" the equilibrium corresponding to the higher temperature and fix the martensite state.

The remarks just made apply, of course, only to the binary solution of carbon in iron. If admixtures of chromium, tungsten, manganese or silicon, etc., are present, we get tertiary and quaternary alloys, and the phenomena become exceedingly complex. Some of these compound steels are self-hardening and owe the name to the fact that they will harden when heated up and allowed to cool slowly in the air, under which conditions ordinary carbon steel would deposit pearlite and become soft.

This phenomenon may perhaps be explained by a shifting of the transition line to lower ranges of temperature—thus, a condition analogous to the martensitic state being maintained at ordinary atmospheric temperatures. Compound steels, however durable and strong they may be, have the disadvantage that on account of their hardness they are extremely difficult to work. The modern trend of development in the manufacture of tool steels is to avoid true self-hardening steels and to adopt a compromise between self-hardening and carbon steels.

The active interest taken in tool steels since the demonstration of the Taylor-White material in 1900 has produced quite a number of steels going by various trade names and requiring a hardening treatment quite similar to that already described for carbon steels.

Each brand of steel possesses a certain hardening temperature to which it should be heated. This hardening temperature corresponds to that state which it is desired to fix permanently by the subsequent rapid cooling process. For compound steels it is 1000° C. to 1300° C. against 700° C. to 900° C. required for carbon steels. Generally speaking, the cooling process for compound steels cannot be so abrupt as for carbon steels. Instead of quenching the hot tool in water or oil, it is usually sufficient to expose it to a current of air or to dip it into tallow.

How any desired temperature for hardening may be obtained by selecting a mixture of different salts in proper proportion is shown above in Table I.

By dipping the cold steel into the heating chamber the temperature of the latter must drop—in fact, with gas-fired furnaces and salt baths it falls rapidly unless the tedious and uncertain procedure of increasing the gas supply is resorted to. In the electric furnace when the tool is dipped into the salt the level rises, the resistance of the bath drops, and current and heat increase automatically. Besides if it should be necessary to immerse large solid masses, the current supply can be easily increased by turning the regulator, thus preventing a drop in temperature. This point is of great industrial importance as it bears on the time in which a certain hardening process can be performed.

Another point which may be of great interest should be mentioned in this connection. In all types of furnaces, except

the electric, the thermal conductivity of the heating medium plays an important part. This medium fills the space between the tool and the heat producer and has to transmit the heat from producer to tool. In muffle furnaces heated by gas or electricity the heating medium is air. In furnaces with a metallic salt bath heated by gas, salt is the medium. The thermal conductivity of air or salt is low. Although the exact value of the latter has not yet been measured, it is safe to state that it is lower than the heat conductivity of iron. The steel can, therefore, transmit through a certain section in a given space of time much more heat than can be carried from the heat producer. The result is an inevitable drop of temperature.

In the electric furnace the heat is *produced* in the salt, not only *conducted* by it, and by increasing the voltage, more heat can be produced than the steel can take up. The speed with which the heating process can be performed is, therefore, not limited by the thermal conductivity of the heating medium and is in actual practice six to ten times higher than obtainable with other types of furnaces.

In the electric furnace the smaller cross-sections of the tool will, of course, also heat up quicker than the large ones, but will not overheat, because they cannot assume a higher temperature than that of the bath itself. The bath equalizes all differences in temperature, and in a very short time heats up the whole mass uniformly. This point explains the very small percentage of waste in electric furnace plants compared with others.

While the tool is in the bath, air is, of course, prevented from coming into contact with it, but a thin coating of salt protects it still further on its way to the cooling tank, and falls away only when placed in the cooling liquid. This is a great advantage over all types of open fires or muffles, but it is common to all bath-type furnaces.

Metal salts, however, offer the additional advantage that they do not give off poisonous gases, and that, unlike lead, they can be obtained comparatively pure at reasonable cost. Furthermore, a salt coating breaks up entirely in the cooling liquid, while with lead sometimes small particles stick to the steel leaving soft points underneath them.

During the heating-up period, or when a certain temperature is exceeded, the metal salts give off a small amount of vapor, and, therefore, hood and chimney are provided. During the normal operation there is scarcely any vapor at all produced. The hood offers the further advantage that the radiation of the bath surface is somewhat diminished, and can be made use of for preheating the articles to be hardened. For this purpose a grate is fixed in the hood on which the articles are placed prior to their being dipped into the bath.

An interesting case, in which the freedom of the electric furnace from smoke or vapor has been found valuable, is the hardening of rock-drills in a South African mine. Here the furnace is placed in a working, the drills are sharpened and rehardened underground, and a considerable saving effected all round.

Concerning the time required for hardening the following results of actual tests are interesting:

A milling cutter of 1355 grams weight (diameter 120 mm, bore 32 mm, width 25 mm) was heated from the temperature of the atmosphere to 1300 deg. C. in 128 seconds. When the same milling cutter had been preheated to 650 deg. C. (dull red heat), the further heating in the electric furnace from 650 deg. C. to 1360 deg. C. required 62 seconds.

A milling cutter of 250 grams weight (diameter 38 mm, bore 17 mm, width 45 mm) required 18 to 24 seconds to be heated from 650 deg. C. to 1300 deg. C.

A steel cylinder of 2250 grams weight, not preheated, required 243 seconds to be heated to 830 deg. C.

A comparison is also given of the comparative costs of the electric furnace and a gas furnace, from a test with 100 millers, each of 5.25 kg, with the following results:

Table II.

	Gas furnace.	Electric furnace.
Cost per miller.....	20 cents	6.8 cents
Time for total process.....	50 hours	10 hours
Cost per hour.....	40 cents	68 cents
Millers in furnace at one time.....	2	1

In other words, the enormous reduction of time required for hardening is at the bottom of the smaller cost of the electric furnace.

In many cases the hardening furnace has made it possible to substitute the rapid direct method for the tedious and costly case-hardening process.

In the discussion which followed the paper, Mr. F. W. Harbord described some of his experiences with the furnace in heating a large number of steel bars from 800 deg. C. to 1230 deg. C. and keeping them at a high and fairly constant temperature for some time; this he was able to do without difficulty. If a furnace could be designed to compete with present large heating furnaces, its possibilities should be very great.

Mr. W. Rosenhain thought the furnace had decided advantages for the hardening and tempering of tool steels. He thought some care would be required in the selection of the fused salts; nitrates, for example, would have an oxidizing effect on steel. Too rapid heating of a piece of metal of uneven cross-section might be undesirable, as expansion stresses would be set up. The uniformity of temperature attained was probably largely due to lagging. He hoped that use of the furnace would throw light on such questions as whether heating to what are excessive temperatures when the metal is exposed to furnace atmospheres is also injurious when the metal is submerged in fused salts.

Mr. C. R. Darling criticised the author's figures for costs of working. In works in which producer gas was available for the gas furnace, the financial superiority of the electric furnace would disappear. He suggested the use of an optical pyrometer for temperatures above 1100 deg. C.

Mr. T. Vaughan Hughes considered that the electric furnace had many drawbacks compared with producer gas-fired equipments, such as too sudden heating, the trouble in dealing with fused salts, and the difficulties of handling large quantities of goods. He was of opinion, too, that its efficiency was low compared with existing furnaces, especially for maintaining comparatively low temperatures. He added some particulars of such gas-heated furnaces, which, he stated, easily realize the advantages claimed for the electric furnace, which, excepting for very precise and scientific investigations, could not compete with a properly designed producer gas-fired furnace.

Mr. W. C. Prebble remarked on the danger of suddenly heating complicated tools.

Dr. J. A. Harker thought that the amount of energy consumed in the furnace could be greatly reduced by improved lagging. The method of heating up the bath initially with a carbon rod seemed liable to difficulties. Had fused fluoride salts been actually used?

Dr. C. H. Desch considered that the furnace did away with the old difficulty of judging hardening by means of skill acquired with the eye. A pyrometer was of no use in an ordinary muffle.

Mr. E. Adler replied to the various points raised. The rate of heating depended on the voltage and was under control. No action of the fused salts on steel had been observed. Mr. Hughes admitted the scientific value of the furnace, but appeared to consider that scientific accuracy was unnecessary for scientific work. Of course, much larger furnaces than those now made could be built, and their efficiencies would increase accordingly. Optical pyrometers might perhaps be used above 1400 deg. C.; for ordinary purposes thermo-couples were pre-

ferable. There was no difficulty in starting the furnace, which took some fifteen to twenty minutes. Fluoride salts had only been used experimentally.

Small Experimental Heroult Furnace.

By C. A. HANSEN.

A year ago we built the furnace shown in the accompanying illustrations, Figs. 1, 2 and 3. It consisted merely of a couple of cast-iron flasks picked up from the foundry scrap heap, two trunnions originally belonging to a small ball mill, and two supporting cradles, such as are ordinarily used for holding ladles around a cupola. These were joined together and a spout—the only special piece made—was added to complete the tilting furnace chamber.

The electrode holders were likewise taken from the scrap heap—two old lathe tool slides. The furnace was kept in a vertical position by holding it up against a stop with a tackle. It was tilted forward by slackening the tackle. Quite recently we found an old tipping slag-car, appropriated the gears and we now have a convenient, respectable tool for experimental work.

To date somewhat more than 200 runs have been made on

well satisfied with the results obtained from the furnace, however small and crude it may seem.

Electrodes.

At first we tried 4 in. x 4 in. carbons as electrodes, but these were unsatisfactory for three main reasons:

1. The carbons available showed a decided tendency to chip off, or split off, at the hot end, especially at the start of a run.

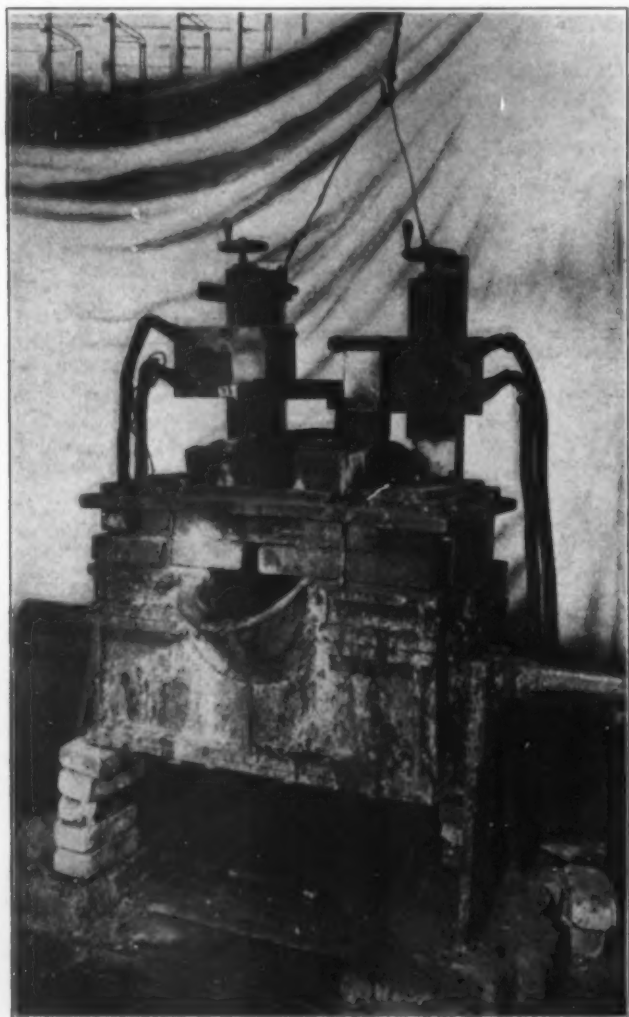


FIG. 1.—FRONT VIEW OF EXPERIMENTAL HÉROULT FURNACE.

very soft steels, high-carbon steels, high-speed tool steels, chrome steels, manganese steels and a variety of special alloys, the charges varying from as little as 50 lb. to 300 lb.

The furnace has been successfully used in experiments where fused ferrosilicon was used as reducing agent for a superimposed low-melting oxide slag. In short, we have been very



FIG. 2.—SIDE VIEW OF EXPERIMENTAL HÉROULT FURNACE.

In several instances one piece after another would drop off until in five or ten minutes the electrode would be too short to reach the bath. This very trying feature was almost entirely overcome by thoroughly drying the electrode and partially, at least, graphitizing the tip. If we put a layer of carbon in the furnace and passed current through it, we succeeded in both thoroughly drying out the furnace lining and in annealing the tips of the electrodes.

2. The furnace was not provided with cooling-water attachments and the poor heat conductivity of the carbons made for local heating at the terminal contacts. This objection could, perhaps, also have been done away with by proper terminal design.

3. Although in straight tensile pull the carbons are about twice as strong as graphites of equal section, they seem more

brittle and in several cases in tilting, and in puddling, when a puddle bar rammed into an electrode, the carbons broke off.

None of these troubles occurred when we used graphite, and it seemed that the saving in nerves and time balanced the very

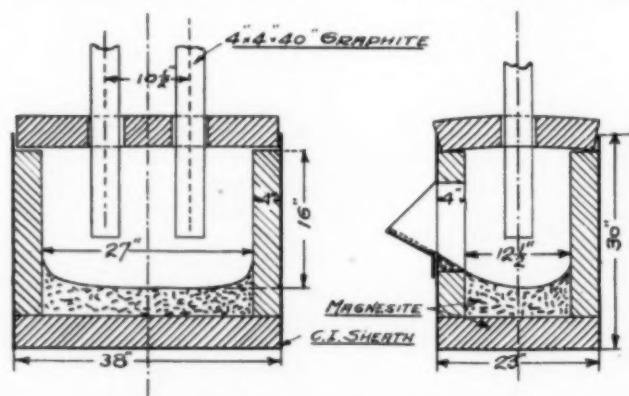


FIG. 3.—EXPERIMENTAL HÉROULT FURNACE.

much increased cost of the graphites. We have, therefore, used 4 in. x 4 in. graphite mainly.

Consumption of Electrodes.

This item has been rather large, due principally to the fact that the furnace was not as tight as it should have been so that considerable air circulated about the electrodes, and partly to the absence of water-cooling attachments which would secure a lower mean temperature of electrode and a consequently lower oxidation loss.

As regards relative consumption of carbon and graphite electrodes the results seemed rather in favor of the carbons. On the average the electrodes were shortened about 12 in. in four runs if unprotected, and 12 in. in six or seven runs if coated with a thin wash of carborundum and water-glass.

Power Consumption.

As regards power, Fig. 4 is reproduced. We were not at all limited in power supply and little precaution was taken to avoid bad power fluctuations. These curves, therefore, represent what happens with rough usage.

Fig. 5 shows the effect of a little care on the power curve. Only the most difficult portion of the run is tabulated in this case—melting a cold charge in a cold furnace. The vertical line drawn at 15 minutes, Fig. 5, represents the time when a bath was completely formed between the two electrodes. The only bad fluctuation on the curve was due to the addition of a

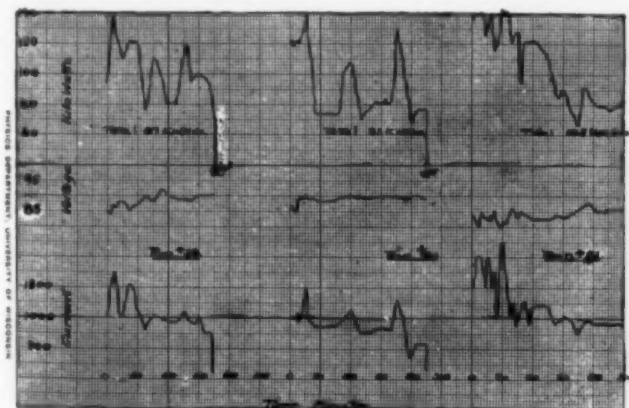


FIG. 4.—LOAD FLUCTUATION CURVES.

rather large ingot head which momentarily short-circuited the electrodes by raising the bath level.

A 150-lb. charge of sheet scrap can ordinarily be melted in a cold furnace with about 70-kw hours. The furnace can be kept hot with 50 kw and the power consumption per unit charge

varies with the time it stays in the furnace. In one balance sheet, covering the melting and partial refining (carbon and sulphur) of 10,000 lb. of metal in 300-lb. charges, the power consumption averaged very close to 150 kw-hours per run, or 1000 kw-hours per ton. In at least half of these runs the furnace was perfectly cold at the start.

Each run was started with cold metal.

Metal Losses.

In the balance sheet above referred to I find we charged 10,000 lb. of metal.

We poured 8540 lb. of sound ingots.

Scrap on hand available for remelting, 980 lb.

Loss, 480 lb. = 4.8 per cent.

This loss would undoubtedly have been very much greater had we attempted to rake off slag for phosphorus removal.

Slags.

We attempted, naturally, to use an all-lime slag as in large-scale practice, but found that it invariably chilled at the base of the spout and hindered the withdrawal of metal from the

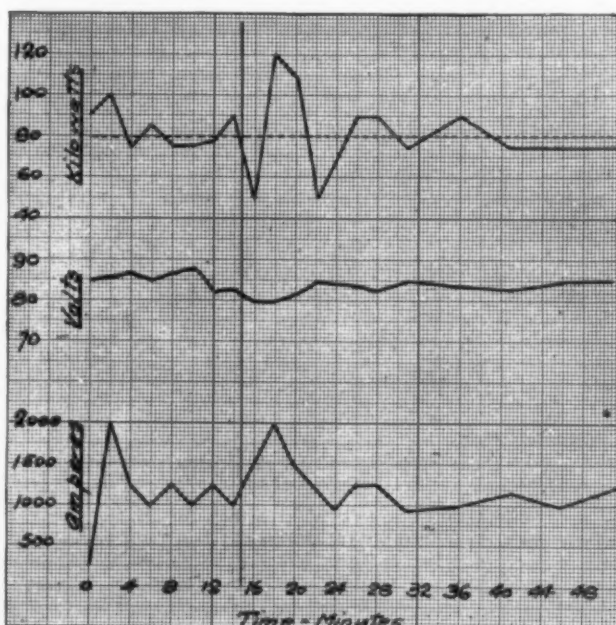


FIG. 5.—LOAD CURVES WITH CAREFUL OPERATION.

furnace. After some little experimenting we settled down to a 5:1 :: CaO : SiO₂ slag. This melted at a sufficiently low temperature so that it did not bother us much by chilling in the spout, and, although it was harder on the basic lining than the all-lime slag, we continued the use of it.

Linings.

The furnace was lined with a 4-in. course of magnesite brick, and this was covered to above the slag line with an inch at the sides, and with 2 in. to 3 in. at the bottom, of sintered Grecian magnesite, crushed to 40-mesh, and put in with a little water-glass. This tamped-in magnesite sintered to a dense, hard lining which, under ordinary conditions, lasted from eight to ten runs. The bricks with reasonable care last indefinitely.

The portion of the lining first attacked is that nearest the electrodes—the fluid slag whirls about with the electrode tip as a center and washes the lining away. A slightly larger chamber in which the lining could be withdrawn a few inches further from the electrode would undoubtedly increase the life of the lining immensely.

Quality of Output.

The following list of analyses covers the results in a dozen consecutive runs on alloy steel, in which the charge consisted chiefly of sheet scrap, averaging: Carbon, 0.2 per cent; sulphur, 0.05 per cent to 0.06 per cent; phosphorus, 0.05 per cent;

silicon, 0.10 per cent; manganese, 0.35 per cent. In general, slag was removed once and a second slag added.

	C.	P.	S.	Mn.
1.....	.13	.053	.014	.140
2.....	—	.019	.010	.076
3.....	—	.024	Tr.	.082
4.....	.082	.022	.012	Tr.
5.....	.067	.021	.012	.053
6.....	.098	.014	.010	.140
7.....	.125	.021	.026	.076
8.....	.071	.030	.026	.079
9.....	.129	.044	.007	.076
10.....	.094	.026	.008	.086
11.....	.130	.041	.013	.112
12.....	.088	.029	.013	Tr.

In making alloys we can generally come very close to the required analyses by adding the theoretical amount of material when neither metal nor both contains appreciable oxidizing matter. For instance, several steels made up to contain 11.5 per cent chromium all analyzed between 10.8 per cent Cr. and 11.5 per cent Cr., which is certainly as close as one could reasonably hope for when working on so small a scale. The slag in these experiments analyzed 2 per cent to 3.5 per cent chromium and weighed about 12 lb. The metal weighed about 200 lb. Obviously the loss of chromium is negligible.

In one experiment, however, the attempt was made to obtain a 5 per cent aluminium steel by adding Al. bar underneath the slag. The analysis of the resulting metal gave 1.2 per cent. Al. and 4 per cent Si. The aluminium had reduced the silica in the slag. The composition required was obtained when alumina or calcium fluoride was used as flux for the lime instead of silica.

The following experiment is detailed to show the availability of the furnace for experimental work.

Two hundred pounds sheet scrap were charged, the bath was deoxidized with ferro-silicon, and the slag removed. A fresh slag was thrown on and fused, then the following additions were made to the neutral bath:

15 lb. FeC	— 4 per cent C
5 " FeSi	— 56 per cent Si
2 " FeMn	— 80 per cent Mn
5 " FeP	— 15 per cent P
2 " FeS ₂	

The log of the run which followed shows the removal of these impurities.

		ANALYSES.						
Time. (min.)	KW.	Additions (lb.)	Slag.	Si.	Mn.	S.	P.	C.
0	100	10lb CaO 2lb SiO ₂						
10	100	Impurities		1.290	.888	.507	.369	.356
20	100			1.050	.578	.227	.336	.331
25	80	4lb Fe ₂ O ₃						
30	80			.354	.380	.180	.346	.334
40	80			.103	.236	.140	.298	.216
41	80	4lb Fe ₂ O ₃ 8lb CaO						
55	80			.029	.163	.084	.193	.112
65	80	{ FeO-12.95% MnO-3.87% }		.028	.135	.099	.203	.081†
66	80	6lb Fe ₂ O ₃						
85	70			.004	Tr.	.107	.074	.063
86	70	5lb CaO						
100	50	{ FeO-3.76% FeO-28.82% MnO-1.41% }		.026	.000	.101	.072	.05
105	50	5lb Fe ₂ O ₃						
120	60			.907	.000	.089	.048	.060
135	0	{ 10lb CaO 2lb SiO ₂ }		.017	.000	.090	.050	.030‡
140	80	2lb FeSi						
150	80							
165	70	{ FeO-24.93% MnO-2.40% }		.022	.000	.046	.034	.069
170	60							
175	60	2lb FeSi						
190	60	1lb FeSi						
200	60	{ CaO-37.95% SiO ₂ -38.81% FeO-8.71% MnO-1.35% S-0.56% MgO-12.74% }		.253	Tr.	.045	.040	.032
220	60							
225	60	10lb CaO						
230	60							
240	0			.200	.124	.047	.050	.034
240	0	Poured off.						

*Neutral bath—200 lbs.

†Very little CO coming off.

‡Raked off slag.

§Glassy, green slag—does not disintegrate.

¶Disintegrating white slag.

I am indebted to Mr. B. R. von Sholly, of this laboratory, for the analyses.

The increasing phosphorus and manganese percentages at the end of the run show the result of leaving behind in the furnace some of the oxidizing slag. It seemed, however, to me that we removed it all.

In conclusion, I wish to point out the value of a furnace of this kind, which is well within the power range available at all of our technical schools, as a means of inculcating some, at least, of the principles of metallurgy. It is certainly evident that a few first-hand runs will do more toward fixing in one's memory the sequence of operations in metallurgy, and the reasons for them, than any amount of mere reading. An open hearth is practically out of the question for such a purpose.

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Dry Chlorination of Sulphide Ores.*

BY F. W. TRAPHAGEN.

The use of chlorine in one form or another is not new to metallurgy, and this element has been the means of adding many millions to the world's store of wealth, chiefly through its use in chloridizing roasting for pan-amalgamation hypsulphite lixiviation and in the vat and barrel chlorination processes.

The proposed new process of dry chlorination of sulphide ores, which is just now attracting so much attention, is, however, totally different in principle from any of the above-mentioned processes, for while they require air in the preliminary operation of roasting, it is indispensable to the success of this new process that oxidation be prevented and the operation carried on so that chlorides are the only products formed.

Reference to the accompanying table will show how important this point is, for it must be borne in mind that the tendency, when chemical changes are taking place, is for those compounds to form which in their combination produce the maximum heats of formation. Furthermore, when conditions, especially temperatures are favorable, these tendencies are the more marked, the greater the differences between the heats of formation of the existing compounds and of those which may be formed by the recombination of the elements. Where the heat of formation of the possible new molecule is but slightly greater than that of the original molecule, the elements show but slight disposition to make new combinations, and the application of external energy is necessary to effect a change.

Keeping these points in mind we see from an inspection of the data in the table that the heat of formation of zinc chloride, for example, is more than double that of its sulphide, while the oxide possesses a value almost equal to that of the chloride.

In like manner the heats of formation of the sulphides and chlorides of the other elements are, respectively: Silver, 3000 and 29,000; cuprous salts, 20,300 and 35,400; cupric salts, 10,100 and 51,400; lead, 20,200 and 83,900; ferrous salts, 2400 and 82,200; manganous salts, 45,600 and 112,000.

HEATS OF FORMATION OF SULPHIDES, OXIDES AND CHLORIDES.

(Adapted from Richards' Metallurgical Calculations.)

METAL.	SULPHIDE.		OXIDE.		CHLORIDE.	
	Molecular Weight.	Heat of Formation.	Molecular Weight.	Heat of Formation.	Molecular Weight.	Heat of Formation. Dry in dil. sol.
Gold	—	—	442.0	11500	303.5	22800 27200
Silver	248.0	3030	232.0	7000	143.5	29000
Copper (ous)...	159.2	20300	143.2	43800	99.0	35400
Copper (ic)...	95.6	10100	79.6	37700	134.6	51400 62500
Lead	239.0	20200	223.0	50800	278.0	83900 77900
Iron (ous)...	88.0	24000	72.0	65700	127.0	82200 100100
Iron (ic).....	—	—	160.0	195600	162.5	96150 127850
Manganese						
(ous)	87.0	45600	71.0	90900	126.0	112000 128000
Manganese (ic)	—	—	87.0	125300	—	—
Zinc	97.0	43000	81.0	84800	136.0	97400 113000

*A paper read at the fourth annual meeting of the Western Association of Technical Chemists and Metallurgists at Boulder, Col., Jan. 6, 1909; abstracted from the March issue of the *Western Chemist and Metallurgist*, the organ of the association.

The heats of formation in the above table are given in gram-calories per gram-molecular-weight for each compound.

In carrying out the process care is taken not to pass in an excess of chlorine, so that only the protochlorides are formed. More energy is developed and the higher chlorides are formed when the partially chlorinated mass is discharged into water and treated with additional chlorine and steam. This brings all the metals into solution, when they are passed through filter presses with wooden frames and separated from the insoluble gangue and sulphur.

The metals may then be successively precipitated by displacement: gold and silver by copper; copper by lead, and lead by zinc. The reduced iron and manganese chlorides are perchloridized by steam and chlorine gas, and precipitated by zinc oxide. The solution thus freed from all the metals save zinc is evaporated to dryness and the resulting zinc chloride electrolyzed with the production of metallic zinc and the regeneration of the chlorine.

Theoretically about 22 lb. of zinc should be produced per hp-day; actual results have been somewhat better than half this figure, and with improved devices may be expected to reach as much as two-thirds of the theoretical figure.

The field of usefulness of this process is very large, but the most promising one is in the treatment of those ores that have so long been a source of anxiety to those owning them, i.e., the complex lead-zinc ores that could be marketed only by sacri-

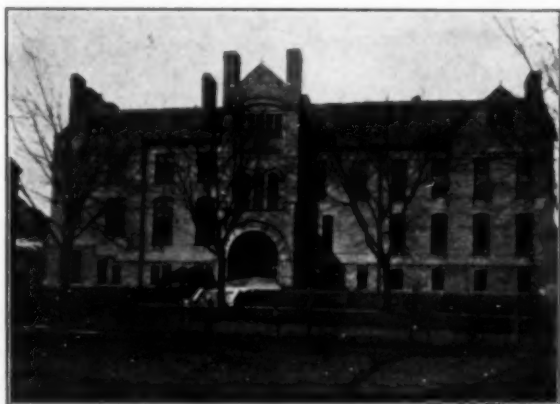


FIG. I.—CHEMICAL ENGINEERING BUILDING.

ficing one or more of the valuable constituents. The process is peculiarly adapted to the treatment of such ores, and the author looks to its development and success in that direction.

Like many other processes, this one is not new, and while Baker and Burwell, Swinburne and Ashcroft, and Alf. Sinding-Larson deserve much credit for their part in its development, they were far from being pioneers in the use of dry chlorine gas with ores, patents having been issued for this purpose as early as 1868.

DENVER, COLO.

Chemical Engineering at the University of Wisconsin.

The University of Wisconsin is one of the few engineering schools in this country offering four-year courses in chemical engineering, as companion courses to the older ones in civil, mechanical, electrical and mining engineering.

In 1895 a course in applied electrochemistry was organized at this institution, and three years ago this was incorporated into the newly established department of Chemical Engineering. Applied electrochemistry, being a branch of chemical engineering, is one of the several lines of work from which the students in chemical engineering have to choose.

The Chemical Engineering Building, the basement and first

floor of which are devoted to needs of the chemical engineering department, is adjacent to the machinery building in which are located portions of the chemical engineering laboratories devoted to metal deposition and refining, storage batteries, electrolytic processes, electric furnace rooms, equipment for power generation, and rooms for experimental research work.



FIG. II.—LABORATORY OF INDUSTRIAL CHEMISTRY.

In the chemical engineering building proper are the class rooms, museum and reading room, offices laboratory for fuel and gas analysis, for the calorimetry and testing of fuels, for electrochemistry, metallography and chemical technology. One room is devoted to pyrometric standards and measurement, containing an extensive equipment of the various available forms of high temperature measuring instruments. The chemical technology laboratory is equipped with vacuum pan, vacuum and other drying ovens, condensers, digestors, filter presses, centrifugals, etc.

One large alternating-current electric-furnace room is supplied with electrical energy from a two-phase, 200-kw alternator, and a direct-current furnace room has 100 kw available from a direct-current generator. Various other forms of electrical energy are also available.

The furnace equipment consists of various types of arc and

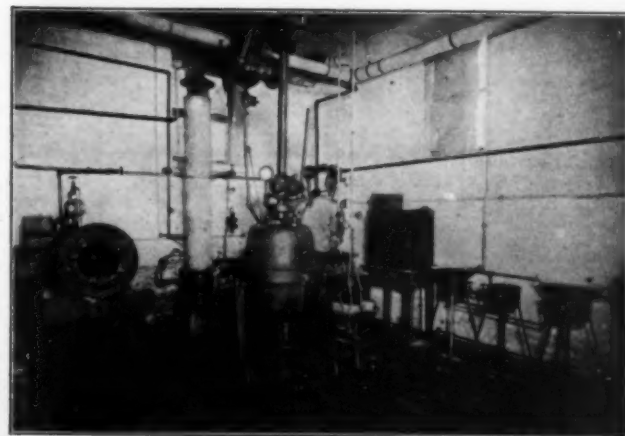


FIG. III.—VACUUM DRYING AND EVAPORATING MACHINERY.

resistor furnaces, muffle furnaces for roasting, gas fired melting furnaces, electrical transformers, regulating apparatus and instruments.

A room adjoining the furnace room is equipped with grinding, crushing and pulverizing machinery, including gyratory and jaw crushers, crushing rolls, buhrstone mill, ball mills, disk

grinders; also mixers, blower, sand blast outfit and magnetic separator.

Two rooms are devoted to plating and polishing of metals, two to the electrolytic refining of iron, and two to storage battery equipment, with several store rooms and research rooms.

These laboratories are designed for undergraduate instruction

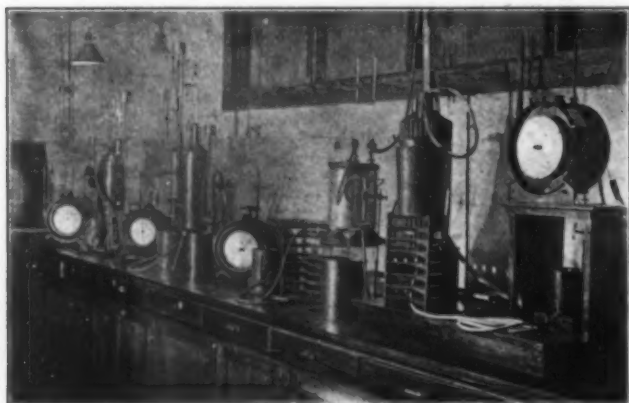


FIG. IV.—CALORIMETER LABORATORY.

work, and also for thesis and advanced research. Numerous lines of experimental work have been and are now under way, and some of these have resulted in the development of industrial methods. Work on the electrolytic refining of iron has been carried on continually for seven years, and several tons of refined iron have thus been produced. This iron is used most largely in the production of iron alloys, of which nearly 1000 have already been made, and about 500 of these have been machined into test bars for magnetic and other tests.

Among the more important lines of electric-furnace investigation may be named the production of molybdenum, of cerium,



FIG. V.—TESTING EFFICIENCY OF A JUNKERS CALORIMETER.

a large number of borides and silicides, alloys of calcium with aluminium, magnesium, zinc, iron and other metals, the reduction of tungsten and the electrical reduction and distillation of zinc.

Extensive study has been given to the roasting of the zinc-iron ores for the purpose of magnetic concentration; the corrosion of iron has been systematically studied for a number of years, and special attention given to locomotive boiler corrosion as an electrochemical phenomenon. Pyrometers are being subjected to comparative tests and an investigation of the commercial efficiencies of gas heaters and various other gas appliances used in domestic work is now under way. An exhaustive study of various calorimeters for determining the heating value of

gas was begun over a year ago, under the direction of a committee appointed by the American Gas Institute.

A considerable portion of the investigation work of this department has been devoted to a study of the problems presented to the Railroad Commission of Wisconsin in its supervision of the gas and electrical industries of Wisconsin.

Several hundred tests have been made upon dry cells and results of investigations along this line have resulted in various improvements which have been incorporated in the commercial product.

Provision is made for two courses of study—one of four years, leading to the Bachelor's degree, and one of five years, leading to the Chemical Engineer's degree.

These courses are based upon the idea that the chemical engineer requires a fundamental training in physics, in engineering



FIG. VI.—FURNACE-ROOM FOR DIRECT CURRENT.

and in chemistry, and while there is much discussion and difference of opinion expressed as to whether the chemical engineer be primarily a chemist or primarily an engineer, it is believed that the course as adopted gives such fundamental training in both lines that the student who has had such training is equipped to enter some of the various important lines of engineering work now coming under the classification of chemical engineering.

It is recognized that a four year's undergraduate course should be devoted most largely to a study of principles and

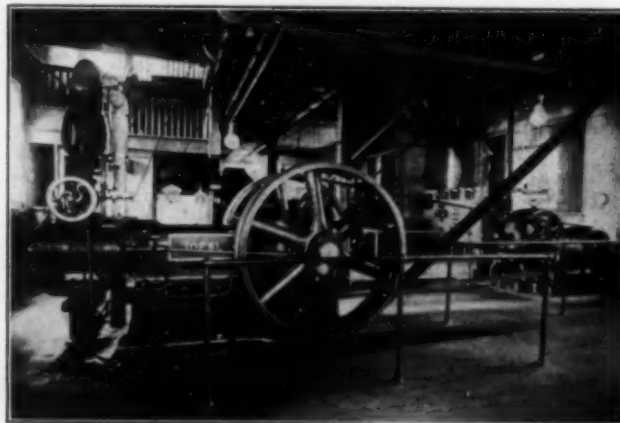


FIG. VII.—150-HP ENGINE AND GENERATOR FOR DIRECT-CURRENT FURNACES.

theories, rather than details of specialized lines, and it is not antagonistic to this idea that opportunity is given to certain elections on the part of students which may enable them to direct their attentions to certain groups of studies. A student who is especially interested and wishes to prepare himself for

electrochemical work may follow the outline of studies laid down in the electrochemical course, while as an alternative, a gas engineering or a metallurgical course may be followed by a suitable selection of subjects.

Under a grant from the Carnegie Institution of Washington an investigation of electrolytic iron and iron alloys has been carried on for four years.

By a recent decision the U. S. Forestry laboratories are to

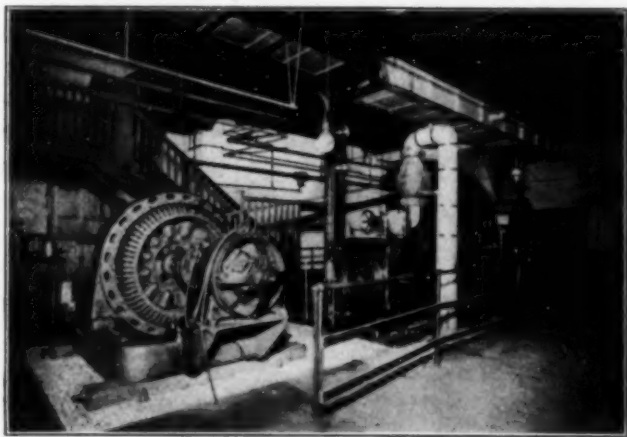


FIG. VIII.—250-HP ENGINE AND GENERATOR FOR ALTERNATING-CURRENT FURNACE-ROOM.

be located in Madison. These laboratories are to be placed in a large building to be constructed this year, and it is planned to provide a research force of 20 or more men. Much of this research work which it is proposed to undertake consists of the recovery of by-products in the wood-working industries and the utilization of wood and forest wastes, investigations which are of particular interest to the chemical engineer.

That there is a growing demand for chemical engineers is evidenced by the increasing number of requests which are being made for students having had this training. This demand for

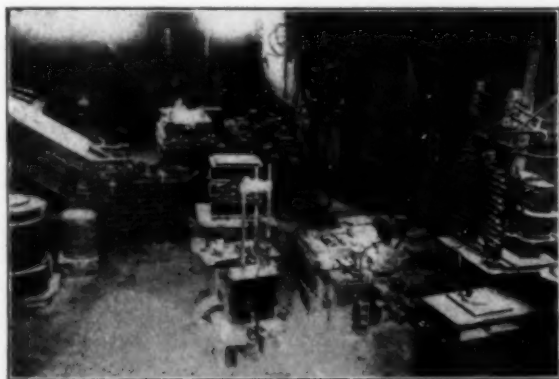


FIG. IX.—FURNACE-ROOM FOR ALTERNATING CURRENT.

chemical engineers comes from a great variety of sources, including the chemical and other manufacturing industries, electrochemical, electric furnace and other similar lines of work; in metallurgy, in the cement and ceramic industries; in the manufacture and distribution of gas. This last is a particularly profitable field for those having chemical engineering training.

The Department of Chemical Engineering of the University of Wisconsin is under the direction of Prof. C. F. Burgess. J. C. Dickerman is assistant professor of chemical engineering. Dr. O. P. Watts, assistant professor of applied electrochemistry, has charge of the electrochemistry work, and Mr. O. L. Kowalke has the division of work relating to pyrometry, calorimetry and testing of fuels, and the manufacture and distribution of gas.

The Evaporator.

BY EDWARD ZAREMBA.

In spite of the fact that evaporators are used in so many industries, the amount of knowledge in circulation concerning them is strikingly small. Thus it happens that the apparatus has reached a far higher stage of development in some industries than others.

At present the finest equipments are to be found in the German and Austrian beet-sugar factories. Similar excellence will be manifest in this country as soon as our manufacturers awaken to the necessity of reducing running expenses to a minimum.

The original evaporator was the old cast-iron kettle suspended over a fire, such as is still used in the woods for making



FIG. X.—FURNACE-ROOM FOR ALTERNATING CURRENT.

maple sugar; then came the open tank heated by interior steam coils. Equipment of this character is far more frequently used than should be the case at this late day. Its one advantage is low first cost; the objections are: (1) high steam consumption; (2) the creation of large quantities of vapor which will fill the operating room with fog; (3) large floor space required; and (4) high maintenance charges.

All these objections are eliminated by the use of vacuum

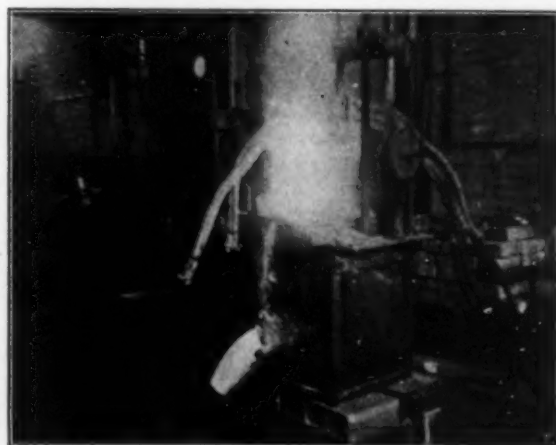


FIG. XI.—80-KW ARC FURNACE IN OPERATION.

apparatus. Where an open tank will demand a consumption of 1.2 lb. or more of live steam per pound of water evaporated, a single effect vacuum pan will do the work with 1.03 lb. of exhaust steam per pound of evaporation. In a double effect the steam consumption per pound of evaporation is reduced to 0.55 lb. and in the case of a triple effect to about 0.35 lb. Furthermore, the amount of condensing water required for a single

effect is reduced by 50 per cent in a double effect and by 65 per cent in a triple.

From one point of view a multiple effect consists of a series of boilers or bodies (two to five) whose heating medium is steam at successively lower temperatures for each succeeding body.

Again, a multiple effect is a series of surface condensers whose cooling medium (the liquor concentrated) is at successively higher temperatures for each preceding body.

Any given body can at any instant evaporate only so much water, or produce such an amount of vapor, as can be condensed in the steam-chest of its following body.

By feeding live or exhaust steam into the steam-chest of the first (high-temperature) body and connecting a vacuum pump and ordinary condenser (jet or surface) to the vapor space of the last (low-temperature) body the steam originally fed can be used as many times as there are bodies.

In plants running non-condensing engines and troubled by lack of sufficient power it is possible, by using a properly designed evaporator, to concentrate the liquor and at the same time have the evaporator act as a condenser for the engines; in other words, the steam can be taken into the evaporators at a vacuum of anywhere from 0 in. to 15 in. or still higher if need be.

The vacuum pan is the most efficient of all heat engines, the only necessary loss of heat being that by radiation, which will run from 5 per cent to 10 per cent in the case of uncovered pans—the low figure being for single effects, the high figure for triples.

Assuming that the workmanship in a vacuum pan is first class and that the heating tubes are ventilated without loss of steam, all forms of apparatus have practically the same steam economy, apart from the radiation loss, which, of course, would be dependent upon the amount of surface exposed.

There is an impression in some quarters that a multiple effect has more capacity than a single effect; this is a mistaken idea, as the function of the multiple effect evaporator is to increase the steam and water economy, not to increase the capacity.

Vacuum evaporators may be roughly divided into two general classes—the submerged-tube and the film type. In the former the tubular heating surface is entirely submerged in the boiling liquor, while in the later type the liquor is either showered over the hot tubes in a sort of continuous rain storm, or a mixture of boiling liquor and vapor globules is forced rapidly through the tubes.

In the submerged-tube type the steam is carried through the tubes with the liquor outside (horizontal tube apparatus), or the steam surrounds the tubes, with the liquor flowing upward through the latter (vertical tube apparatus).

The objection to the film type is its delicacy, being very apt to get out of order; furthermore, it is difficult to control the final density of the liquor. The main objection to the submerged-tube type is its comparative high first cost. However, when costs of operation and maintenance are taken into consideration they are found to be much cheaper in the long run.

A more or less elaborate equipment of pumps is required, the most important being the vacuum pump, which removes the non-condensable gases from the condenser. The tail pump removes the finished liquor from the final pan. The function of condensation pumps is to remove the condensed steam from the various steam chests working at less than atmospheric pressure. A circulating pump for the liquor concentrated is required in the case of certain film types using a forced circulation of liquor. In submerged-tube evaporators the circulation is automatically induced by the action of the vapor generated.

All forms of vacuum apparatus call for the use of a condenser, in which the vapor coming from the last pan is condensed by contact with cold injection water. In the wet system the air and gases present are entrapped in this warm mixture of condensed vapor and injection, the entire mass being withdrawn from the system by a wet vacuum pump and discharged.

In the dry system of condensation the condenser is made much larger and is mounted sufficiently high (about 34 ft.) to allow the water discharged to flow into the hotwell by its own weight against the pressure of the atmosphere. In this case air and non-condensable gases only are handled by the vacuum pump.

The term "barometric condenser" is generally used to signify a system similar to the dry system, except that the vacuum pump is eliminated by so constructing the condenser that air and other gases are entrapped in the outflowing water. As an offset to the omission of the pump the barometric condenser must be mounted considerably higher in order to secure the same results; furthermore, the water consumption is much greater.

As a rule the amount of water required varies from 25 lb. to 30 lb. per pound of vapor condensed. One of the great advantages of the wet system lies in the fact that such a condenser can generally be made to draw its own supply of injection from a neighboring stream or tank. The dry system always requires a circulating pump. There is a large supply of warm water at about 110 deg. Fahr. coming from the condenser, which can frequently be used to very good advantage. The first pan delivers a quantity of distilled water at 212 deg. equal to the amount of steam used; this is preferably returned to the boiler. From the condensation pumps another supply of warm water is obtained at a temperature between the two former.

The steam pressures ordinarily carried vary from 5 lb. down to atmospheric pressure; the vacuum from 23 in. to 27 in.

There are two ways of handling the concentrated liquor. One method, "batching," calls for the carrying of the concentration of the entire body of liquor in the final pan to the proper finishing density, after which the heavy liquor is removed by the tail (or magma) pump. In the other method, "continuous," the heavy liquor settling in the bottom of the final pan is withdrawn by the pump while the pan continues in operation.

The multiple-effect evaporator, although seemingly mysterious in its action, if properly designed, is easily operated—the work being generally performed by unskilled labor. The chief care of the operator should be to preserve the greatest possible uniformity of conditions as concerns the pressure of steam, height of the vacuum, rate of liquor inflow, and the drainage of the steam chest. As soon as he has become familiar with these points the rest is a mere matter of routine; henceforth the evaporator should require very little attention. A good evaporator is like an excellent employee—the less watching and interference the greater the results produced.

A New Norwegian Calcium Carbide and Cyanamide Works.

The large amount of water power available in Sweden and Norway has resulted in recent years in the establishment of numerous new industries. According to recent estimates, the following amounts of water power are available and partly developed:

	Available.	Developed.
Sweden	4,000,000 hp.	400,000 hp.
Norway	5,000,000 "	500,000 "

The figures given under "developed" refer to plants actually in operation or in course of construction.

Owing to the widely differing conditions, the hydro-electric plants are of very different types, suitable for heads from less than 3 ft. up to 3290 ft., and to deal with quantities of water up to 9900 cu. ft. per second. Our excellent London contemporary, *Engineering*, has recently published in the numbers of March 12 and 19, some interesting illustrated descriptions of five different typical plants.

From these articles we have extracted the following figures, which are particularly interesting with respect to the cost of

power development. The first three figures under "cost per electric hp" are actual costs, the plants being finished. The last two figures are estimated costs, but believed to be approximately correct, the plants being not yet completed.

	Turbine hp	Feet head	Cost per electric hp.
Joesefors, Sweden	1,800	26	\$70
Frykfors, Sweden	4,000	27	64
Yngeredsfors, Sweden	8,250	60	38
Vamafos, Norway	75,000	86	26
Tya, Norway	73,000	3290	36

The last two plants are particularly interesting to electrochemical engineers. The Vamafos plant belongs to the company exploiting the Birkeland-Eyde process, and the Tya plant to the Badische Anilin und Soda Fabrik. Both plants are to be used for the fixation of atmospheric nitrogen. As was mentioned in our last issue, page 147, the Birkeland-Eyde concern has reached an understanding with the Badische Company and the results to be obtained at the experimental plant at Notodden in comparative tests with the Birkeland-Eyde process and the new process of the Badische Company will decide which of the two processes is to be finally adopted for large-scale manufacture.

In its issue of March 26 and in following issues, London *Engineering* describes in greater detail another Norwegian hydro-electric plant, situated at Odda, on the Søndrefjord, for the manufacture of calcium carbide and cyanamide.

The erection of these works has had considerable influence on the prosperity of the district in which they have been established. Odda, at the top of one of the most beautiful fjords, was formerly merely a resort of tourists. The tourist season, however, is short, and the measure of prosperity resulting from passenger traffic very limited. Now, however, the population has multiplied threefold; an air of unobtrusive prosperity permeates the district, and influences also a wide area, owing to the increased demand for food, fruit and other supplies.

Those responsible for the design of the carbide and cyanamide works, too, have taken precaution not to materially injure the amenities of the district, and have, for instance, as a result of many experiments, introduced the sprinkler system for dealing with smoke and other products of combustion from the carbide furnaces.

The works were originated by an English company, organized to manufacture and sell a special acetylene plant designed for a dry process. When they had perfected their system, they discovered that a serious obstacle to the commercial development of the scheme was the uncertainty of the supply of calcium carbide.

They succeeded in demonstrating that with carbide at a reasonable price villages, country houses, isolated railway stations, railway carriages, and dock, tunnel and other such engineering works in progress would be illuminated with acetylene at a less cost than would ordinary coal-gas, alike in capital and working charges. But few cared to incur even the small capital outlay involved in the acetylene-generating plant, with an insufficient and in some measure uncertain supply of carbide.

Mr. A. E. Barton, who was at the head of this acetylene company, entered into the negotiations for the purpose of combining several undertakings, including the Alby works in Sweden, and for the construction of new works on such a scale as to ensure a continuous and cheap supply of carbide.

Odda was selected not only because of its convenience of approach from the sea, but because of the proximity of a waterfall owned by the Aktieselskabet Tyssefaldene, and suitable for the generation of electricity which enters largely into the cost of manufacture. A hydro-electric power installation has been constructed to give 23,000 electrical hp, although the available water makes 75,000 hp to 80,000 hp possible of realization when required.

Carbide works have been organized, and a cyanamide factory added, in order to convert the carbide into calcium cyanamide

(trade name "nitrolim") for use as a fertilizer. The total producing capacity of the works is 32,000 tons of calcium carbide and 12,500 tons of nitrolim per annum.

Every effort has been put forth not only to ensure uniformity of results, but the highest economy, and, consequently, the establishment represents the most modern practice in this branch of electrochemistry. This success in manufacture depends upon three factors.

The first, concerned with the ensurance of absolute uniformity in production, requires the selection of the purest raw materials. The anthracite, from which the carbon is obtained, is specified to have not more than 3 per cent of ash; and the limestone must have as little as possible of magnesia and alumina. The coal used is got from Wales and the limestone from the quarries which the company have purchased because of the suitability of the stone, situated at Skaferun, near Bergen, and Levanger, near Trondhjem. In addition, the company owns quarries elsewhere in Norway. Both the raw materials, as well



FIG. 1.—TYPICAL VIEW OF TYSSERIVER AND COLLECTING AREA.

as the gas-coal for firing the limekilns, are brought by water transport to Odda.

The second and still more important of the desiderata is to obviate any great variation in the temperature in the electric carbide furnaces. These furnaces are worked at from 2800° C. to 3000° C., equal to 5360° Fahr to 5270° Fahr.

The third element is economy. Each furnace is of 1400 kw capacity and gives from 7 to 8 tons of calcium carbide per day of 24 hours. Cheap electricity is a primary essential, and this has been achieved by the hydro-electric installation.

Again, each ton of carbide manufactured involves the use of about 2000 lb. of calcined lime and 1300 lb. of anthracite. The supply, transport, and particularly the handling of this material at works where operations are carried out, as at Odda, on a large scale give opportunity for ingenuity in devising conveying facilities.

A system has been worked out for handling the materials as nearly completely automatically as possible.

A careful analysis was made of the cost of unloading the coal and lime and of transporting it by cableway to silos about

1000 yd. distant, where it is stored, in order that the squad of men employed might be paid on the premium system. The standard rates evolved from this analysis work out at 35 ore (about 9 cents) per ton of limestone, 45 ore (12 cents) per ton of anthracite coal, and 40 ore (11 cents) per ton of gas-coal. In a day of 10 hours as much as 300 tons have been unloaded, conveyed by cableway and discharged into the silos, the men employed including two crane-men and 27 laborers at the wharf and one at the silos. One man's time suffices for the transport of the material from the hopper-doors of the silo into four out of the five kilns (one is a stand-by) which are in operation, the

Tysse, which flows into the Sondrefjord at a point four miles from Odda. The Tysse is a typical river of western Norway. Its source is the dark Ringedalsvand, whence it flows surging and leaping through wild and narrow ravines, having a fall of 436 m (1430 ft.) in a distance of about four miles. The Ringedalsvand is the natural regulation basin for the largest part of the rain-collecting area, which is mainly situated on the highlands of the Hardangervidda, about 1000 m to 1200 m (3280 ft. to 4000 ft.) above sea-level, the higher points and valleys being in the region of eternal snows.

Fig. 1 gives a typical view of the Tysse River and Fig. 2 a

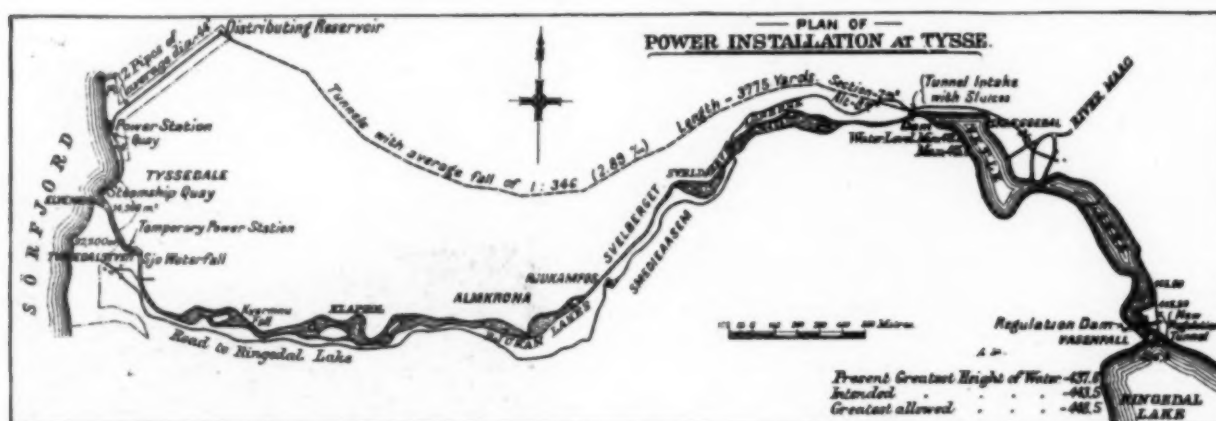


FIG. 2.—PLAN OF TYSEE POWER DEVELOPMENT.

rate of combustion being a total of 190 tons per day of 24 hours in the four kilns.

The limestone cars work on the level by electric traction, and up the incline to the charging platform of the kiln by cable haulage. They only need to be filled at the silo-hoppers and sent on their way, each being automatically tilted at the kiln for which its contents is destined, by reason of the tipping gear differing for each kiln. The same economy of labor characterizes each operation in the whole process of manufacture.

The calcined lime and the anthracite coal are similarly conveyed in buckets, having electric motors, traveling on a Telfer railway to the electrically operated breakers adjacent to the electric furnaces. The ladles with the carbide from the furnaces are taken by overhead rail to the cooling house, and thence by conveyors to the breakers and sifters, which, discharging through hoppers and shoots, enable the finished material to be loaded into export tins according to the size of the cubes. From first to last the only handling is in charging the electric furnaces, a work which is not mechanically done, as the best results are got by the manual distribution of the material.

Electrically worked conveyors are similarly used in the cyanamide works, where the principal operations consist in the separation of nitrogen from atmospheric air by the Linde process, and the subsequent reaction between the nitrogen gas (which must not contain more than 0.4 of oxygen) with calcium carbide in electric furnaces, whereby calcium cyanamide is formed, containing 20 per cent of nitrogen.

The furnaces are of 1-ton capacity per week, taking at each charge one-third of a ton, and are worked at a temperature of 800° C. to 1000° C. (1470° Fahr. to 1832° Fahr.). The furnaces are portable and are moved to the charging position by overhead crane.

The resulting cyanamide is reduced to powder in electrically operated crushers and distributed by elevators and conveyors to the silo—a building 164 ft. long, 131 ft. wide and 20 ft. 6 in. high. Like the calcium carbide, it is packed mechanically for export. The oxygen, obtained by separating the nitrogen from the air by the Linde process, is also marketable, and it is proposed to have a plant for the manufacture of sulphate of ammonia from by-products.

The source of hydraulic power for the turbines is the River

plan of the works; they are also reproduced from the *London Engineering*.

The collecting area is 380 sq. km (94,000 acres), made up of small valleys forming rows of lakes or gorges with bare, rugged rocky slopes. A shower of rain thus forms hundreds of brawling, rushing streams, which ultimately discharge into the Ringedalsvand, 5.5 sq. km (1360 acres) in area, and with a summer water level of 436 m (1430 ft.) above sea level. There is only a distance of 3.5 km (2 miles) as the crow flies from lake to fjord, where the power station is located, so that the conditions were favorable for the construction of a pipe line to the power station.

In calculating the possibilities of power output the annual rainfall was assumed as 2.5 cu. m per meter area, which gave



FIG. 3.—POWER HOUSE.

from the complete area an average yearly supply of 1000 million cu. m (35,317 million cu. ft.), or 25 cu. m (833 cu. ft.) per second. Observations in 1906-7 gave the average flow per second as 30 cu. m, and for 1907-8 as 26 cu. m with a loss of 20 per cent by evaporation, etc.

The higher rate in the former year was due not so much to the rainfall as to the higher temperature during the summer whereby the quantity of snow melted was greatly increased. Therefore 25 cu. m per second seems a fair average.

For the present 6 cu. m (212 cu. ft.) per second suffices to

maintain the output at the required capacity of 23,000 electrical hp, developed by the five generators of equal capacity. But it would be quite possible by augmenting the storage capacity, and by adding to the number of supply pipes and turbo-generators, to get sufficient water power (20 cu. m per second) to develop 75,000 or 80,000 electrical hp.

In Norway, as in Switzerland, it is during the winter months that there is difficulty in maintaining the supply of water. During the winter the fall consists of snow, and the lakes are frozen from November to June.

To enable the water to be drawn from the Ringedalsvand when it is frozen over a regulation tunnel has been formed having its inlet about 16 m (52 ft.) below normal water level.

is avoided any great overflow from the basin in the event of the turbo-generator coming to a standstill, as the water would ultimately flow over the dam at the lake.

The pipe lines have each been designed to supply sufficient water to three turbines, of a total water consumption of 3.6 cu. m (127 cu. ft.) per second. The construction of the line was necessarily a difficult undertaking, because of the steep gradient. The incline, indeed, is probably the greatest in the case of any pipe line, one section, 160 m (525 ft.) in length, being at an angle from 45 deg. to 55 deg. Three-quarters of the line was too steep for the workmen to ascend and descend without the aid of ropes.

The power station, as shown in Fig. 3, is constructed close

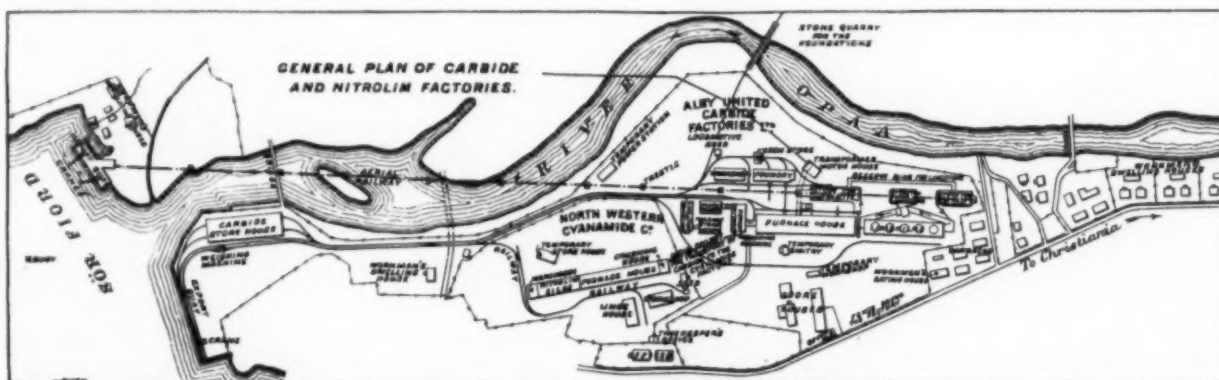


FIG. 4.—PLAN OF CARBIDE AND CYANAMIDE WORKS.

This short tunnel discharges into the lower lake, from which the water passes to the tunnel and pipes to the power station. There is thus maintained a supply at seasons when little water is flowing over the regulating dam between the lakes. This tunnel is 160 m (525 ft.) long.

For the further regulation of the water level in the Ringedals lake a dam was built across its outlet with its crest 448.5 m (1470 ft.) above the sea. It is of the following measurements: Length, 280 m (918 ft.); height, 16 m (52½ ft.); breadth at top, about 2.25 m (7 ft. 4 in.), and at the base about 12 m

to the water level, with sufficient room for extension on the north side. The building, as at present completed, is 50 m (164 ft.) long, and 11 m (36 ft.) wide, and has a large engine room accommodating the six generators now installed. There is adjacent to the power station an import quay, with an overhead crane. From this quay a railway track runs into the main engine room of the power station.

There are six turbo-generators in a row in the center of the engine room. Each unit is arranged with its axis across the hall, the turbines being to the right and the dynamos to the



FIG. 5.—VIEW OF CARBIDE AND CYANAMIDE WORKS.

(39 ft.). The level of the lake is thus raised to increase the storage capacity by about 160,000,000 cu. m. The main dam is, however, at the foot of the Velt Lakes, where also is the inlet to the main tunnel for supplying pressure water to the turbo-generators.

The tunnel from Velt Lake discharges into a basin constructed at the top of the precipitous slope down which the pipes have been laid. This basin is oblong on plan and is 18 m (59 ft.) deep, the bottom being on the same level as the tunnel outlet, 397 m above the sea, while the top is at the same height as the crest of the dam at the Velt Lake. In this way there

left. The water enters beneath the floor from the right through the different valves, and leaves the turbines through the tail-race, which is under the floor level and between the foundation piers for the dynamos. The turbines are of the Pelton wheel type, with automatic regulation, on a design by Messrs. Escher Wyss & Company, of Zurich.

The dynamos are by the Almann Svenska Elektriska, A. B. Westeras, Sweden, and work on the three-phase alternating system, with a tension of 12,000 volts and a frequency of 25 periods. They run at 375 r.p.m., developing 4600 hp, and the output of the generators is 4400 electric horse-power.

Each turbine is coupled direct to its corresponding generator, and five sets run synchronously to produce 20,000 hp at the terminals of the switchboard at the carbide factory at Odda. The sixth set is kept in reserve. Two exciters are installed at the north end of the station, which give 200 electrical horsepower when working at 24 revolutions, the voltage being 100.

The current is transmitted to Odda, four miles distant, at 12,000 volts.

Fig. 4 is a general plan of the carbide and cyanamide factories, while Fig. 5 gives a view of the works, showing from left to right the Sondre Fjord, Odda, the cyanamide silos and furnaces, the carbide furnaces, and the lime kilns.

On the banks of the fjord there has been constructed of timber an import quay, which is entirely independent of the export wharf. Alongside the quay there is a depth of water of 22 ft. at low water, the rise and fall of the tide at this point (110 miles from the sea) being 6 ft. to 9 ft. At this wharf, which is about 50 m (164 ft.) long, there are two cranes, the lifting power of each being 2 tons.

The material raised from the holds of the ships by the cranes is deposited into hoppers, from which tip-wagons are filled, and are then run on the quay level to the cableway station, where the wagons are automatically weighed and afterwards automatically gripped to the cable on the aerial railway.

This cable railway extends from the quay along the course of the Riven Opaaen, and through the works to three silos, arranged respectively for the storing of 2000 tons of anthracite, 2000 tons of limestone, and 1500 tons of gas-coal. The wagons are passed from the aerial cableway to a telfer railway, extending along the top of the three silos, and provided with movable tipping-levers, so that the workmen at the silo can arrange for the automatic teeming of the contents of each car into any of the hoppers of any of the silos.

The limestone cars may also be shunted to a sliding over a reserve bin; as shown on the plan, Fig. 4. The silos are arranged with hopper-bottoms, chutes and doors at frequent intervals.

The material, when required for the manufacture of calcium carbide, is filled into cars running on a telfer track, and having their own electric-traction motors. Current is taken from the overhead conductor, which is divided into circuits coincident with the distance between the hopper-doors, so that the workman, when he has released the contents of the silo-hoppers into the car, may switch on the current to enable the car to travel either to the producer in the case of the gas-coal, to the kiln in the case of the limestone, or to the anthracite hopper, in communication with the breakers, in the case of coal for the carbide furnaces.

The charging platform of the lime-kilns is at a high level, and cable traction has been adopted for the gradient. The calcined lime is similarly conveyed by electric cars on a telfer railway from the discharge doors of the kilns to the mixing-room, which forms part of the electric-furnace house.

Here the two main constituents of the furnace charge—lime and anthracite—are automatically weighed in double-compartment wagons, mixed, and lifted to the charging platform of the electric furnaces. As already explained, the furnaces are charged by hand, as this ensures a better mixture of the contents.

There are five kilns, each of 30 tons capacity, in a house alongside the limestone and gas-coal stores, as shown, with their cone-shaped chimneys in the perspective view, Fig. 5.

In line with this building is seen the electric-furnace house, with twelve electric furnaces, each of 1400 kw capacity, producing from 7 to 8 tons of carbide per day of 24 hours. The furnaces are teemed into special ladles, which are taken up by an electric high-level telfer railway, and their contents deposited as a flat, square block on the cooling house benches, where it is broken up into lumps, and as such subsequently taken by band-conveyors, to the extensive plant for breaking it up into

cubes of the desired size, or direct to the cyanamide or nitrolime works.

From first to last, the handling of the material is almost entirely mechanical. In the same way labor-minimizing machinery has been introduced for the manufacture of the drums and the covering wooden cases in which the carbide is exported.

The nitrolime works form a continuation of the carbide works, and are seen on the left of Fig. 5, the largest building being the silos. The Linde house, shown on the plan, Fig. 4, contains the refrigerating machinery, by means of which nitrogen and oxygen are extracted from the air by liquefaction. The Linde plant is run by a 200-hp motor and produces 375 cu. m (13,244 cu. ft.) of nitrogen per hour.

Calcium carbide, pulverized in the crushing house shown in the plan, is fed through hoppers and chutes into the portable furnaces, which are then placed on the furnace benches and there have connection with the nitrogen gas mains, and with the electric conductors for the electrodes. There are 200 furnaces in the furnace house, operated at 75 volts, to maintain a temperature of 800 deg. to 1000 deg. C. (1475 deg. to 1830 deg. Fahr.).

The cyanamide or nitrolime is crushed and taken by belt-conveyors and elevators to the silos. There is a warehouse for nitrolime as well as carbide.

The export quay is built of stonework, and has a length of 100 m (328 ft. 1 in.) and a width of 12 m (39 ft. 4 in.). There is an electric traveling crane, designed to load 50 tons of carbide per hour, the lifting capacity being 1 ton.

Aluminium Electrolytic Condensers of High Capacity.

For many purposes, for improving the power factor of alternating-current networks or for starting single-phase synchronous motors, etc.—practical condensers of high capacity would be very desirable. The cost of such condensers, made with solid dielectrics, like mica or paper, would, however, be prohibitive.

On the other hand, it is easy to make aluminium electrolytic condensers of high capacity. They may become even of practical value, if a pure capacity without any energy losses is not required. The weak point of aluminium electrolytic condensers, as compared with mica condensers, is that they have considerable energy losses.

The aluminium electrolytic condenser has been discussed in two American Electrochemical papers of Mr. C. I. Zimmerman (our Vol. II, p. 182, and Vol. III, p. 172). It has recently been the subject of an investigation of Dr. GÜNTHER SCHULZE, carried out in the German Reichsanstalt and published in *Elektrotechnik und Maschinenbau* (Vienna), March 14.

The "critical voltage"—that is, the maximum voltage which an aluminium anode will stand without letting any appreciable amount of current pass—is given for aluminium in different electrolytes in the following table, for 0.1 equivalent normal solutions after 24 hours of formation:

TABLE I.			
Na ₂ SO ₄ ,	40 volts	Na ₂ SiO ₃ ,	445 volts
KMnO ₄ ,	112 "	NH ₄ HPO ₄ ,	460 "
(NH ₄) ₂ CrO ₄ ,	122 "	Ammonium citrate,	470 "
KCN,	295 "	Na ₂ B ₄ O ₇ ,	480 "
NH ₄ HCO ₃ ,	425 "		

The valve effect of the aluminium anode is due to an exceedingly thin oxide or hydroxide film on the aluminium plate, covered by a thin gas layer, the resistance of which per square centimeter amounts to millions of ohms. Such an anode may be considered as a condenser. In comparing such an anode to an ordinary solid condenser, the gas layer corresponds to the dielectrics, and the aluminium anode and the electrolyte correspond to the two plates of the condenser.

The capacity of this condenser depends only on the voltage

of formation and the material of the anode and is independent of the nature of the electrolyte.

Fig. 1 gives the capacity as function of the formation voltage for aluminium, tantalum and magnesium. The abscissas are the voltage of formation, the ordinates, the capacity per square centimeter surface. The second set of curves in this figure shows the increase of calculated thickness of the gas layer with increasing formation voltage.

By passing from lower to higher voltages, the thickness of the gas layer increases and assumes its new value within a few minutes. By passing back from the higher to the lower volt-

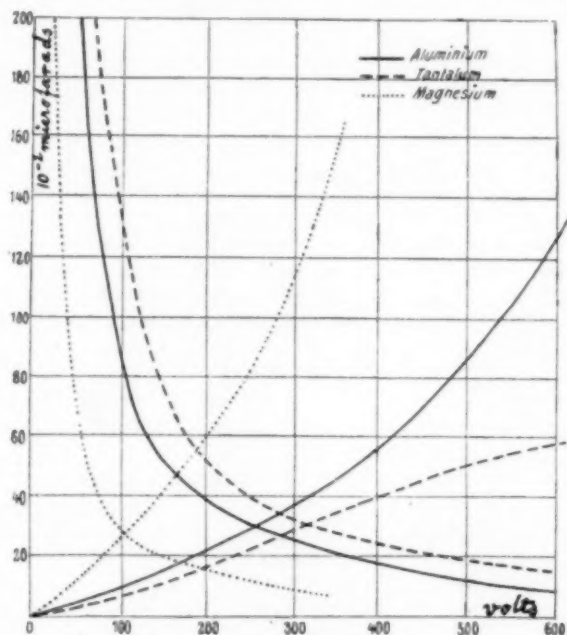


FIG. 1.—EFFECT OF FORMATION VOLTAGE.

age, however, it takes months until the thickness of the gas layer is reduced again to its former value.

For short experiments the thickness of the gas layer may be considered as constant, as long as the voltage remains below the voltage at which the anode was formed. In this case the electrolytic condenser behaves like a condenser with unchangeable dielectrics.

If, however, the formation voltage is increased, the capacity is inversely proportional to the formation voltage.

The aluminium electrode shows the valve effect only as long as it is anode, while it permits the current to pass freely when it is cathode. An electrolytic condenser must therefore be made of two aluminium (or magnesium, etc.) plates. For any direction of the current, only the one electrode which is anode, produces the condenser effect. An electrolytic condenser has not necessarily the same capacity in opposite directions of the current. To assure this, both electrodes must have an equal surface in the electrolyte and must be formed at the same voltage.

In the practical manufacture of electrolytic condensers attention is to be paid to the fact that the oxide film and the gas layer adhering to it cover only those parts of the aluminium electrode which are in the electrolyte. From those points of the aluminium surface which are just above the electrolyte the electric current tries to jump over from the aluminium plate into the electrolyte, causing considerable heat and corrosion of the aluminium. It is, therefore, important to make this aluminium boundary line between electrolyte and air as short as possible and to insulate it very carefully.

The aluminium condenser used in Schulze's experiments contained 10 aluminium plates of the dimensions of 9.7 cm x 16.5 cm x 0.1 cm. Each plate was cut near the top, as indicated at a and b in the left-hand top diagram of Fig. 2. The two

strips, thus formed at the top on both sides, were then bent upward (see left-hand bottom diagram of Fig. 2), and the plate was then reversed (i.e., the two end strips downwards) and suspended in an $\text{NH}_4\text{HB}_2\text{O}_4$ solution, so that the two strips were in solution, and the plate just touched the electrolyte.

Formation was then carried out at a maximum voltage of 500 volts. In this way a resistant oxide film was produced, as indicated by the dark-lined portion in the left-hand bottom diagram of Fig. 2. From the upper ends of the two strips the oxide film was again removed in order to make good connection with the copper wires leading to the external circuit. A close-fitting piece of rubber pipe was then placed over aluminium and copper, around this a glass tube with an insulating compound, and around this again a piece of rubber pipe, as shown in the right-hand diagram of Fig. 2.

This method of insulation prevented, with few exceptions, any corrosion of the aluminium plates at the boundary line between electrolyte and air during the experiments, which lasted several months. The total length of the boundary line was only 6.4 cm for a total plate surface of 3250 sq. cm.

The residual current ("reststrom") was very small. For instance, after the condenser had been connected for several weeks to a direct current = voltage of 110 volts, the residual current became constant = 0.0005 amp. If we assume that the current density over the whole surface was uniform, the current density was 0.00000015 amp per square centimeter, or the resistance of the gas layer per square centimeter surface was 733 megohms.

But, as a matter of fact, the residual current, after connection to constant voltage for a long time, was always found to be smaller the shorter the length of the boundary line for the same electrode surface. This indicated that the residual current passed almost completely through the boundary line, while the residual current through the gas layer over the rest of the surface tended to become zero.

The different aluminium plates of the condenser were fitted with the glass tubes in a fiber plate which formed the cover of the cell. Either a glass vessel was used, when it was desired to render the condition of the electrodes visible, or a painted brass container, when it was desired to cool the electrolyte effectively.

In order to facilitate the formation of the aluminium plates with direct current, a platinum electrode was inserted in the electrolyte and served as cathode, while the aluminium plates were all connected in parallel and served as anodes.

When used with alternating current the odd numbers of the plates formed one pole and the even numbers the other pole. The mean distance between any two plates was 0.5 cm.

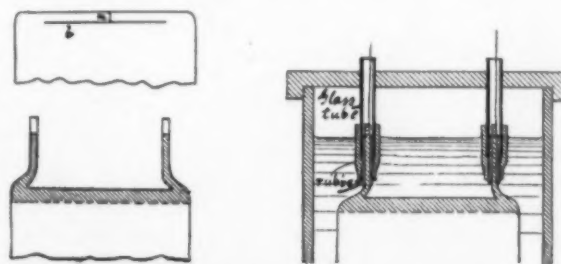


FIG. 2.—CONSTRUCTION OF CONDENSER.

A saturated solution of $\text{NH}_4\text{HB}_2\text{O}_4$ was used throughout as electrolyte, being apparently the most suitable one.

For alternating-current tests of aluminium electrolytic condensers it is advisable to form the aluminium plates with direct current at that voltage which corresponds to the maximum value of the alternating-current voltage to be applied during the tests.

For the final tests an alternator was used giving approximately a sinusoidal voltage curve. The condenser was connected for several days to a direct-current pressure of 40 volts

and was then connected to the circuit of the alternator, the maximum voltage of which was the formation voltage of the condenser. The results are given in Table II.

TABLE II.

Duration of tests in minutes.	Curr't voltage loss of condensers. Amp. Volts. Watts.			Temperature of electrolyte.	Power factor.	Capacity in microfarads.	
0	1.27	27.6	1.95	19.2° C.	0.056	146.7	After formation at 80 volts for four days. Residual current 0.0045 amp. Maximum voltage of alternating current of test = 84 volts.
10	1.27	27.6	1.90	19.3	0.054	146.7	
120	1.26	27.4	2.25	19.7	0.065	146.3	
0	1.36	59.3	4.5	17.7	0.056	73.1	After formation at 40 volts for several days. Residual current 0.003 amp. Maximum voltage of alternating current of test = 39 volts.
10	1.35	59.2	4.0	17.8	0.050	72.6	
60	1.35	59.2	4.0	18.0	0.050	72.6	
0	1.34	113.0	6.8	19.3	0.044	37.7	After formation at 160 volts for six days. Residual current 0.0037 amp. Maximum voltage of alternating current of test = 159 volts.
3	1.36	112.6	11.3	19.3	0.074	38.4	
10	1.46	112.1	16.5	19.7	0.101	41.3	
30	1.60	112.5	30.5	21.0	0.114	45.0	During one week the d.c. voltage was held constant at 110 volts, the circuit being repeatedly broken and the poles reversed. Residual current 0.0025 amp. Maximum voltage of alternating current test = 132 volts.
60	1.72	113.4	23.0	22.8	0.118	48.3	
0	1.32	93.7	10.0	20.0	0.081	44.9	
10	1.33	93.7	10.6	20.2	0.085	45.2	
60	1.43	93.8	12.4	21.9	0.092	48.5	

Frequency - 50 N.

Table II shows that the energy losses are low with an alternating voltage of 27 or 59 volts and hardly increase when the condenser is connected to the circuit continually for an hour or two. But an increase of the losses in time is evident at 93 volts and assumes quite a considerable value at 130 volts.

When the condenser had been formed with direct current at 400 volts and was then employed at an alternating voltage of 250 volts, the power factor increased to 0.3.

If other electrolytes than borates are used, the losses are probably even higher, since with borates the constancy of the gas layer is a maximum and the residual current is a minimum.

In the case of condensers to be used without interruption for a longer period, it is, therefore, advisable to make the voltage for one condenser not higher than 90 volts, and to connect several condensers in series for higher voltage.

The capacity given in the seventh column was calculated by multiplying the current with the sine of the angle of phase difference and dividing by voltage $\times 2\pi$. This calculation is permissible only if the currents and voltages have sine waves. By special experiments this was found to be true.

Some results of Table II are quite interesting. The capacity current was constant = appr. 1.3 amp, independent of the voltage applied, as long as the maximum value of the alternating-current voltage was approximately the voltage of formation.

After the third series of experiments (carried out at 113 volts effective) the condenser was connected to a direct-current voltage of 110 volts for about a week, the circuit being repeatedly broken and the poles reversed. It was then connected to an alternating-current circuit of 80 volts effective (maximum value, 117 volts). The capacity current was then found to be only 1.13 amp (instead of 1.32); this indicated that the thickness of the effective gas layer had not been reduced to the value corresponding to 110 volts, but much less, namely, to a value corresponding to 132 volts (maximum value). When tested at this voltage the current was again 1.32 amp, as shown in Table II.

A second important conclusion from Table II is that the product of capacity and formation voltage is almost constant. From the four series of tests of Table II we find:

Volts.	Microfarads.	Product.
40	147.7	5870
80	73.1	5850
132	44.9	5930
160	37.7	6030
	Mean,	5920

The slight increase of the product with the voltage is due to the fact that the capacity of the upper rim of the plates (formed at 500 volts) manifests itself more strongly the higher the formation voltage of the plates.

On the basis of the mean value 5920 for the product, the capacity for 100 volts formation pressure would be 59.2 microfarads.

According to the curve in Fig. 1 the capacity of 1 sq. cm aluminium surface at 100 volts is 0.0858 microfarads. The total surface of the condenser was 3250 sq. cm, of which, however, only 2800 can be considered as effective (subtracting the strips at the top and the upper rim of the plates).

Each of the two equal electrodes has, therefore, at 100 volts a capacity of $1400 \times 0.0858 = 120$ microfarads.

The measurements, however, as stated above, give only 59.2 microfarads, that is, just one-half.

This is, of course exactly right, as has already been pointed out by Zimmerman. The evident reason is that at any moment only the one plate which is anode is effective as condenser while the other plate permits the current to pass.

This fact must be taken carefully into account in designing a condenser of desired capacity. The useful capacity corresponds to only one-fourth of the total aluminium surface in the electrolyte, as for either direction of the current only one-half is to be taken into account and only one-half of this can be utilized.

Finally, Schulze mentions a test of the condenser with an alternating current of higher frequency and its behavior when used for a longer period.

The results of the tests at higher frequencies were as follows:

Frequency.	Voltage.	Capacity current in amperes.
803	102.8	25.6
815	82.8	21.8
823	73.6	19.4
836	59.2	15.0

When the condenser was connected to the circuit for more than a week and the current and voltage were gradually raised from 1.1 amp and 66 volts to 2 amp and 120 volts, while the temperature of the electrolyte increased to 45° C., the condenser stood this test without a visible change.

Notes on Electrochemistry and Metallurgy in Great Britain.

(From our London Correspondent.)

Faraday Society.

At the meeting of March 2 papers were read by Dr. V. H. VELEY and by Drs. VELEY and CAIN on "The Rate of Evolution of Gases from Homogeneous Liquids."

The conditions of the evolution of gases from liquids by processes of chemical change were studied, with especial reference to the degree of supersaturation, which appears to have been greatly over-estimated.

The amounts of gases so retained were calculated by comparing the volumes which were actually evolved and those which would have been obtained if there had been no retention. From the solubilities of the several gases in water, the only data available, the supersaturation values were determined. It appears that this value does not exceed 8 to 12, according to the nature of the gas and conditions of experiment.

The lag factors due to certain opposing side reactions are also discussed for a few cases, and their effects separated from the concomitant initial delay due to gas retention.

The papers elicited quite an extended discussion. Mr. F. E. Weston said he had given considerable attention to the subject since 1898, but anomalous results and lack of opportunity to fully investigate had not permitted his experiments to be fulfilled. He described briefly his methods of experimenting, and stated that he found it possible to keep the temperature con-

stant for a whole working day to one-tenth of a degree centigrade when the bath had been adjusted. In many experiments when the final reading had been taken, the liquid in the bath was stirred by the thermometer, and the further evolution of nitrogen was observed; but the volume of nitrogen so liberated would not account for the decrease noted in the velocity-constant. Mr. Weston furnished observations of two typical sets of experiments; the volumes of gas evolved were the means of three sets of observations for each temperature, the individual observations differing by amounts varying from 0 to 2 per cent from the mean.

Dr. J. C. Cain considered that the omission of a thermometer in the reacting liquid in Mr. Lamplough's experiment threw great doubt on all the results recorded by him. He questioned the value of a blank experiment where temperature was concerned, especially in measuring velocity-constants, which varied enormously with temperature. He also pointed out that the decomposition of a diazo salt was exothermic, and he himself had invariably observed that the heat evolved in experiments performed at higher temperatures was great enough to raise the temperature of the solution by 2 deg. to 3 deg. This fact, in conjunction with the record of Mr. Lamplough's method of heating the diazo solution "one or two degrees higher" than the temperature of the bath might fully account for the higher figures of the velocity constants obtained. Taking his own value in the case of diazo-benzene chloride at 50 deg. to be correct, then Mr. Lamplough's value would correspond with 53.5 deg. Mr. Lamplough had questioned the contention of Cain and Nicoll that their experiments confirmed earlier observations on the unimolecular nature of the reaction, but he doubted whether numbers which agreed, but were to be found for any other unimolecular reaction. A comparison of the results of the worst experiments of Cain and Nicoll and of Lamplough indicated that the differences were of the same order in each case. It was noteworthy that in Mr. Lamplough's experiment at 36 deg. the facts recorded were practically all alike, notwithstanding inherent errors in observation.

Mr. Lamplough dealt with the experimental justification of his method, and briefly stated how he had ascertained the values for the degree of supersaturation obtained in his experiments on the decomposition of diazo-benzene chloride. He directed particular attention to the fact that in the experiment with agitation of the solution there was no evidence of any departure from unimolecular law in the experiment: without stirring the action simulated a unimolecular action for a limited range, but with a much lower velocity-constant. With regard to the decomposition of formic acid, the speaker gave an extract from Dr. Veley's paper (*Phil. Trans.*, 1888, p. 264), vividly describing the effervescent action produced by introducing silica into a mixture of formic acid and sulphuric acid which had been allowed to react for 25 minutes without agitation, and further experiments with formic and sulphuric acids described in the same paper. Mr. Lamplough considered that the calculations in pages 4 to 6 were open to serious objection, which opinion he proceeded to sustain; and in conclusion stated that he did not consider his apparatus favorable to the attainment of high degrees of supersaturation, as he believed that if more favorable conditions were adopted much higher values than 100 times the normal saturation amount might be obtained for the degree of supersaturation.

Dr. Santer said that the fact that there is often considerable supersaturation when gases are generated in a liquid had been known for many years; and recently it had been widely recognized that where rates of reaction were estimated by measuring the rate of evolution of a gas, the results could only be entirely depended on when there was continuous agitation of the solutions. It followed that the facts were perfectly well known by recent publications on the subject, concerning which there has been so much discussion. As to the want of agreement in opinion between Dr. Cain and Mr. Lamplough he desired to recall the fact which had so far not been referred to that evening,

namely, that the vessels in which Dr. Cain's solutions were treated contained a large quantity of glass beads; and the increase of surface so obtained must have considerably reduced the tendency to supersaturation. The comparatively simple formula put forward by Dr. Veley could not, in his opinion, represent the state of affairs in a quiescent (and therefore supersaturated) solution with any great degree of accuracy.

With reference to Dr. Cain's and Dr. Veley's paper, Dr. E. Feilmann said that an important question arising from that very interesting paper was that of the state in which the gases existed in a supersaturated liquid. Judging from recent views of the nature of colloidal solutions, it seemed possible that the gas was present in particles of almost molecular dimensions, which slowly aggregated to greater masses until their tendency to rise overcame the viscosity of the liquid. Probably such minute particles of gas would be electrically charged, and the decomposition of the solution of ammonium nitrite under the influence of an electric field in a gas voltameter would be of considerable interest if it were noted whether the liberation of nitrogen occurred largely or entirely at one pole in preference to the other. The observation whether an increase in the viscosity of the liquid caused by the addition of a protective colloid, such as gelatine, increased the amount of supersaturation also deserved attention. He was aware that Findlay had already published results of experiments on the augmented solubility of gases in colloidal solution; but the conditions in such a case would not be identical. Why the gas evolved from a homogeneous liquid should tend to form at one point more than at another was not easy to understand; and it appeared that the conditions closely resembled those existing in an ordinary superheated liquid, and consequently it might be expected that a very unstable system would be obtained under suitable conditions.

The National Physical Laboratory.

Absence from London prevented my utilizing the invitation to the annual inspection at the National Physical Laboratory at Teddington. Instead, therefore, of commenting on new apparatus and methods of research from an actual visit to the place, I am compelled to glean from the annual report of last year's work notes of metallurgical interest for these columns.

Electric Laboratory Furnaces.—In the thermometric division much of the time of the staff has been given to the organization and equipment of two new laboratories. Reference should be made to the new spiral tube carbon furnace designed by Mr. W. A. Price and Dr. Harker, and to the remarkable increase in efficiency reached in the ordinary type of platinum resistance furnace by proper attention to the design. In the old furnace of the original platinum resistance design, having an internal capacity of 100 cc, the expenditure of 3300 watts was needed to reach a temperature of 1350° C. The new furnace has a capacity of 150 cc, and the same temperature can be reached by the expenditure of 1400 watts.

In connection with the tests on new resistance alloys, and also on various samples of an alloy used for making resistances for use in the laboratory, it has been found that the temperature coefficient varies considerably with different samples of the same alloy, and also with different sizes of wires of the same batch of material. Some preliminary tests have been made, and it is proposed, in conjunction with Mr. Rosenhain, to investigate the discrepancies fully.

In connection with the new thermometer testing baths for the thermometry department, a series of experiments was carried out at the suggestion of Mr. W. A. Price, with a view to devising a satisfactory form of electric heating unit. The form finally adopted was to wind a thin strip of "Eureka" resistance material on a thin sheet of mica, the electrodes of copper strip being then threaded into the mica and hard soldered to the Eureka strip. A thin sheet of mica is laid on each side and sewn around the edges, and the whole is slipped into a thin copper envelop, which is let into and soldered to the lower side

of the bath. This envelop being a nice fit round the mica, the unit can be easily removed for renewal or repair, without moving or emptying the bath. Some of the units have been in use for several months for heating baths up to 100° C. without a single case of breakdown. Each unit is made in two sections, each of which will take 4 amperes at 100 volts, i.e., a total of 800 watts per unit, and by means of suitable switches they can be put in series, or singly, or in parallel, as occasion demands.

In the thermometry department, Mr. W. A. Price and Dr. Harker have perfected the details of a type of furnace in which most of the defects of the carbon-tube furnace are absent. One great advantage of the new type is that its resistance is not limited solely by dimensional considerations, but may be chosen to suit the experiment and the supply of current available. In the new form of furnace the carbon tube is retained as a lining only, the heat being supplied by the current in a graphite spiral, surrounding, but carefully insulated from the central tube.

Three sizes of furnace have now been made and run successfully. In the last of these the heater was machined from a tube of graphite of 3 in. external and 2 in. internal diameter, the ventral portion being cut on a lathe to form a spiral of 16 turns, the thickness of the turned portion being $\frac{3}{8}$ of an inch, the pitch 2-3 in. and the space between the turns $\frac{3}{16}$ in. Through the center of this spiral passes a long tube of arc lamp carbon of $\frac{3}{4}$ in. internal diameter. This tube is insulated from the spiral and serves to carry the bodies to be heated.

The heating current is led in and out of the spiral by means of two flattened copper tubes, $\frac{3}{4}$ in. diameter, resting as saddles on the solid ends, good contact between the copper and carbon being insured by a layer of tinfoil, a weight of 10 lb. being hung on a crossbar, joining the two limits of each saddle below. The current is supplied to these bars by stout cables of dynamo flexible. Through the copper tubes a water circulation is maintained, which completely prevents any serious heating.

The whole furnace is mounted in a cubical cell built of fire-brick of about 2 ft. wide and covered externally with a cement dressing. It is supported on a slab of York stone by walls 3 ft. high, over a trench in the floor of the furnace room. To prevent oxidation of the heating spiral, this is packed in a thick layer of lamp black, made from vegetable material and containing very little inorganic matter.

The lagging of the furnace consists of bricks and slabs of magnesia boiler covering, these being arranged so as to stop any convection currents inside the furnace as completely as possible. This furnace attains a temperature of 2000° C., with 150 amperes at 40 volts, while the average life of the type is much greater than that of the older pattern. It has been employed for the determination of a number of high melting points for the standardization at high temperatures of optical pyrometers. It will also be used for baking tubes, thermometer reservoirs and other articles made of rare earths.

Chemical Elements and Electronic Theory.

In the course of his presidential address to the Chemical Society, Sir WILLIAM RAMSAY said that his subject was the hypothesis that the genuine difference between elements was due to their gain or loss of electrons. The question was whether, to take a concrete example, an atom of sodium by losing or gaining electrons remained an atom of sodium, or whether the loss or gain of electrons did not cause it to change into some other element or elements.

Having stated some theoretical arguments in favor of the possibility of transformation, he went on to describe some experiments bearing on the question. He first mentioned the transformation of radium emanation into helium, which had been amply established. He next referred to his experiments on the action of emanation on solution of copper sulphate and nitrate. Four experiments were made, and with each exactly similar duplicate experiments were tried in which no emanation was employed. A larger residue was obtained in each case from

the emanation solutions than from the duplicates, and, while the residues from the emanation solutions showed a faint trace of lithium, those from the duplicates failed to give spectroscopic evidence of the presence of that element.

The fact of the experiments having been carried out in duplicate rendered inapplicable the criticism of Prof. Hartley that accidental contamination with lithium was probable. As regards the alleged repetition of the experiments by Mme. Curie and Mlle. Gleditsch, who, using platinum vessels, obtained no greater residue and no trace of lithium, there were two possible replies—either the conditions were varied, or conceivably a trace of lithium from the glass vessel employed (which, however, had been tested for lithium with negative result) was dissolved in presence of emanation and copper, but escaped solution in absence of copper or of emanation.

A research on the action of emanation on solution of silver nitrate contained in a silica bulb yielded negative results, but he had stumbled across a case of apparent transformation while working in a totally different direction. On Dec. 20, 1905, 270 grams of purified thorium nitrate were dissolved in about 300 cc of water, and the flask in which the solution was contained was repeatedly evacuated by a mercury pump until no gas could be pumped off. The stopcock attached to it was then closed, arrangements being made so that if any leakage occurred it would be detected. After the flask had stood for 168 days the gas in it (5.750 cc) was pumped out and examined for helium, with doubtful results. The flask was again closed, and on Aug. 3, 1907, after 173 days, the gas in it was again examined. Again the presence of helium was questionable, but 1.08 cc of carbon dioxide was found. At the next examination of March 30, 1908, there was distinct evidence of a helium spectrum, and the gas contained 1.209 cc of carbon dioxide.

It was then thought possible that the carbon dioxide had been produced from the grease of the stopcock, and therefore a little mercury was introduced into the capillary tube leading to the stopcock, so that the latter was protected from contact with the thorium solution. After 310 days the gas was again withdrawn. Instead of 3 cc or 4 cc, no less than 180 cc were collected; it was almost pure nitrogen, but in all 0.622 cc of carbon dioxide was separated from it.

These experiments, Sir Wm. Ramsay said, rendered it at least probable that thorium engendered carbon dioxide, or, in other words, that carbon was one of its degradation products. Experiments further indicated that the action of radium emanation on thorium nitrate solutions was also attended with the formation of carbon dioxide, and the same was the case with an acid solution of zirconium nitrate. An experiment with lead chlorate proved blank, but with bismuth perchlorate the formation of carbon dioxide appeared certain.

In conclusion, Sir Wm. Ramsay, after mentioning that every precaution which could be thought of was taken to exclude foreign gas, said that, while these were the facts, no one was better aware than he how insufficient was the proof, and that many other experiments must be made before it could be confidently asserted that certain elements when exposed to "concentrated energy" underwent degradation into carbon.

London, March, 1909.

SYNOPSIS OF PERIODICAL LITERATURE.

Industrial Electrochemistry.

Electric Steel in England.—The progress which the electric steel furnace has made in England is summed up by F. M. Perkin in the London *Electrician* of March 26, as follows: Messrs. Edgar Allen & Company, of Sheffield, are building a 3000-kw furnace of the Héroult type. There is a 60-kw experimental Roechling-Rodenhauser furnace in operation at Battersea. The National Physical Laboratory have also a small experimental furnace, which was presented to them by the Roechling-Rodenhauser Company. It is also understood that

the Anderson electric steel furnace will shortly be in operation in Sheffield. This furnace is of the smothered-arc type and is supported on trunnions in order to facilitate tilting and pouring. The electrodes pass through the furnace cover, and may either be connected in parallel or series. Immediately below the electrodes, and beneath the base of the furnace, is a powerful electromagnet, which is used to control the arc. This is the chief novelty of the furnace and is stated to very much increase its efficiency. Vickers, Sons & Maxim have an induction furnace, but whether they are doing much or little with it is not made public.

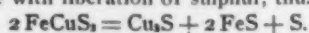
Ferrosilicon.—In the *London Electrician* of March 26, F. M. Perkins remarks that ferrosilicon is a splendid, acid-resisting material. It has been most successfully employed for making condenser works for nitric-acid plants and for the evaporation of acids. Ferrosilicon also forms very useful electrodes for the electrolysis of fused salts. (See the article by Jouve in our Vol. VI, p. 321.)

Calcium.—In an article by F. M. Perkin, in the *London Electrician* of March 26, the manufacture of metallic calcium by the electrolysis of the chloride is said to be slowly progressing, but unless more outlets are found for the use of this metal it will never be a large industry. It has been tried in place of aluminium for "thermit" reactions, but the low price of aluminium, and also of silicon, which has been found useful for these reactions, will prevent metallic calcium being employed, even if it were as satisfactory as these. Probably the chief use of calcium is as hydride, which it has been suggested might be employed as a ballast for balloons and then for regenerating hydrogen gas for long aerial voyages. After being acted upon by water and the hydrogen gas having been given up, the lime remaining could be thrown away, thus also lightening the car.

Calcium Carbide in Japan.—As noted in *London Electrical Engineering* of March 18 Japan is now about to supply all the calcium carbide required for her home consumption, which is estimated at 90,000 kg per month. A new power station has been erected by a company, with a capital of \$300,000, on the Falls of the Soki, near Kagoshima, where water power capable of generating 10,000 hp is available. There are two qualities of carbide manufactured in Japan, the better grade costing about 3.7 cents per pound, and the inferior grade, which is useless for lighting purposes, 1.5 cents per pound. It is even contemplated enlarging the works in order to manufacture calcium carbide for export.

Copper from Ores.—In an article by F. M. Perkin in the *London Electrician* of March 26, we find the following note on the production and refining of copper directly from its ores. This does not seem to be much nearer attainment than heretofore, although attempts are continually being made in this direction. One of the chief difficulties is the large amount of gangue which has to be leached out, and the consequent loss of electrolyte or leaching material. It appears, however, that an attempt is being made in this direction in the English Lake district. At one time considerable profits were made by mining copper at Coniston, but it is a long time since operations were given up. There remain, however, large dump heaps which contain from 1.5 to 2 per cent of copper, and it is proposed to recover this by a process of T. Scott Anderson, of Sheffield. The company holding the patents and who hope to carry out the operation is the Annandale Copper Mines & Smelters (Ltd.). The electrical energy necessary will be obtained from water power, which is stated to be plentiful in the neighborhood.

Another process of O. Froelich (described more fully in *Elektrochemische Zeitschrift*, November, 1908), is as follows: In all previous processes the ore is first roasted in the air. In this process the ore is heated out of contact with air from 200° C. to 300° C.; this converts the ore into cuprous and ferrous sulphide with liberation of sulphur, thus:



The ore is subsequently leached out with ferric chloride, which

dissolves the copper as cupric and cuprous sulphide. The copper is then thrown out by addition of iron and can be further purified by casting into anodes and electrolyzing. When the copper is thrown out by the iron the noble metals remain in the leaching solution, from which they are easily recovered.

Acetylene Chlorides and Ethane Chlorides from Electrolytic Chlorine.—In the *London Electrician* of March 26, F. M. Perkin refers to a new outlet for electrolytic chlorine which has been particularly developed in Germany, namely, the formation of acetylene chlorides and ethane chlorides. The starting materials in this case are all electric or electrolytic. Calcium carbide is produced in the electric furnace, which, when acted upon by water, yields acetylene. The acetylene is then caused to combine with electrolytic chlorine, with formation of acetylene chloride, dichloride and so on up to perchlorethane C_2Cl_4 . These products come onto the market as solvents for oils and fats, and, being practically non-inflammable, they will probably in time be largely employed in place of the inflammable solvents—benzine, carbon-disulphide, etc., at present used.

Electrotyping and Plating.—Recent progress in these arts in England is summed up by F. M. Perkin in an article in the *London Electrician*, March 26, as follows: In place of the wax or gutta molds employed for reproducing electros, recently celluloid sheets have been used. Sheets of celluloid are warmed so that they become plastic and then placed over the positive a reproduction of which is required. They are then hydraulically pressed as usual, the interior surface blackleaded, coated with copper in the usual way by rinsing in copper sulphate and sprinkling with iron filings. After this they are washed and placed in the depositing bath. The process has not come into at all general use. The chief advantage claimed is that, after removing the deposit, the mould can be stored indefinitely and employed again and again, because the removal of the deposit does not appear to injure it. "In reference to the electroplating industry there is not very much new to report. There have been, as usual, a great number of formulas published and patented. In a good many of these the addition of organic substances to the electrolyte has been recommended. Thus, for example, extract of liquorice root and other similar extracts, sugar and yeast, to give a fermentation bath, and so on. Probably platers would be well advised to leave the majority of these rather messy concoctions severely alone."

Zinc Plating.—In an article by F. M. Perkin, in the *London Electrician* March 26, the remark is made that electrolytic zincing only makes very slow headway, probably partly owing to the appearance of the deposit—matt gray. By burnishing the electrolytically deposited zinc will take on a beautiful and brilliant polish, but this means a second operation, and is not readily applicable to irregularly shaped articles. Dr. Carl Richter finds that by keeping the bath slightly acid (1/38 to 1/20 normal), brilliant deposits which show a leafy, crystalline surface can be obtained. He keeps his bath at atmospheric temperature, and employs a current density of 740 amp per square foot, with a potential drop of 0.75 to 0.85 volt.

Ozone for Purification of Water.—In the *London Electrician* of March 26 F. M. Perkin states that the purification of domestic water by means of ozone is gaining ground in Europe. The Lahmeyer Electric Company have placed a very neat apparatus upon the market which automatically purifies the water as it is drawn off from the supply tap. The turning on of the tap sets the ozonizer in operation, and the flow of the water draws the ozone through it. The water thus leaves the pipe in a sterilized condition. There has been an interesting discussion in the *Times*, initiated by Sir Oliver Lodge, as to whether the breathing of limited quantities of ozone is injurious. "Some persons consider that catarrh is caused by the inhalation of the gas mixed with air. It would appear to be rather a question of personal idiosyncrasy. Personally I have found the opposite effects, colds having been cured by working in an atmosphere containing ozone." Although the amount of energy

used in the production of ozone is comparatively small, yet if this method of water purification were to come more into use it might help to fill in the valleys of generating stations. There should be no great difficulty in arranging to work the ozonization during times of light load, and, in order not to inconvenience the users, to store the sterilized water in reservoirs.

Sterilization of Water by Ozone.—According to *Le Genie Civil*, Vol. 54, page 57 (abstracted in *Elek. Zeit.*, March 18) there is a water purification plant in Chartres, in France, for treating 6000 cu. m of water from the River Eure in 24 hours. The water is first filtered through sand and coke and the number of bacteria is thereby lessened to about one-fifth the original value. The balance is killed by means of ozone. The Otto ozone system is used. An alternator provides current at 250 volts and 500 periods. This high frequency is necessary to obtain a good efficiency for the production of ozone. The voltage of the single-phase current is raised to 20,000 and at this pressure the current is supplied to the electrodes of the ozonizer. The purification of 1 cu. m of water requires 2 grams of ozone, corresponding to 50 watt-hours. Recent improvements are expected to increase the efficiency still further.

Theoretical and Experimental.

Electric Laboratory Furnaces.—From the report of the director of the (British) National Physical Laboratory (Lond. *Engineering*, March 26) we note that Dr. J. A. Harker and Mr. W. A. Price have perfected the details of a type of furnace in which most of the defects of the carbon-tube furnace are absent. In the new form of furnace the carbon tube is retained as a lining only, the heat being generated electrically in a graphite spiral, surrounding, but carefully insulated from the central tube. The graphite spiral can expand without causing trouble at the contacts. The spiral is cut on a lathe from a graphite tube of 3 in. and 2 in. external and internal diameter, the turned groove being completed with the aid of a knife. On the ends rest the weighted saddles of flattened copper tubes, forming the water-cooled terminals. The whole furnace is mounted in a cubical cell built of firebrick of about 2 ft. wide, and covered externally with a cement dressing. It is supported on a slab of York stone by walls 3 ft. high, over a trench in the floor of the furnace room. To prevent oxidation of the heating spiral, this is packed in a thick layer of lamp black, made from vegetable material, and containing very little organic matter. The lagging of the furnace consists of slabs and bricks of magnesia boiler-covering these being arranged so as to stop any convection currents inside the furnace as completely as possible. This furnace attains a temperature of 2000 deg. C. with 150 amp at 40 volts. It has been employed for the determination of a number of high melting points for the standardization at high temperatures of optical pyrometers. It is also used for baking rare earths. Properly baked tubes of the rare earths can be heated in the oxy-hydrogen flame and dipped into cold water, being as indifferent to sudden temperature changes as fused quartz.

Electric Heating Unit for Thermometer Tests.—In connection with the new thermometer testing baths for the Thermometry Department of the (British) National Physical Laboratory, a series of experiments were carried out at the suggestion of Mr. W. A. Price, with a view to devising a satisfactory form of electric heating unit. The form finally adopted was to wind a thin strip of "Eureka" resistance on a thin sheet of mica, the electrodes of copper strip being then threaded into the mica, and hard soldered to the Eureka strip. A thin sheet of mica is laid on each side, and sewn round the edges, and the whole is slipped into a thin copper envelop, which is let into and soldered to the lower side of the bath. This envelop being a nice fit round the mica, the unit can be easily removed for renewal or repair without moving or emptying the bath. Some of the units have been in use for several months for heating baths up to 100 deg. C. without a single case of breakdown. Each unit is made in two sections, each of which will take

4 amp at 100 volts; i.e., a total of 800 watts per unit, and by means of suitable switches they can be put in series, or singly, or in parallel as occasion demands. This note is taken from the report of the Director of the (British) National Physical Laboratory for 1908, published in abstract in the *Lond. Electrician* of March 26.

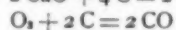
Effect of Electrolytes on Colloids.—The well-known precipitation of colloids by the addition of a trace of an electrolyte to a colloidal solution is the subject of a paper by E. F. Burton in the April issue of the *Philosophical Magazine*. He has studied the action of electrolytes on copper colloidal solutions and sums up his chief results as follows: For a copper colloidal solution, the particles of which are positively charged (i.e., move to the cathode), the influence of added electrolytes on the velocity of the particle has been determined. The electrolytes used were potassium ferricyanide and aluminium sulphate. Evidence has been produced to show that it is the ion bearing a negative charge that is active in reducing the velocity. This power of the negative ion depends on the valency in a way analogous to the valency relations found by Picton and Linder, and by Hardy, for the coagulative power of ions. The discharging power of two negative ions of the same valency is the same. Observations on the coagulation produced in each case shows that the particles coagulate when they lose their charge.

Synthetic Ammonia.—In London *Engineering* of April 9 we find the following note on the synthetic preparation of ammonia which still remains practically an unsolved problem. The two gases nitrogen and hydrogen do not react on one another at ordinary temperatures; at higher temperature the combination is facilitated by the presence of certain catalysers like iron, but the resulting ammonia is not stable at 1000 deg. Cent., the temperature at which Haber and Oordt experimented. (We should mention, however, that a successful electric-arc process is now spoken of.) It has hence been attempted to make use of metallic nitrides and hydrides; but the just-mentioned experimenters did not find the dissociation pressures of the nitrides and hydrides of calcium and manganese suitable, and E. Baur and Voerman do not recommend chromium-nitride for other reasons. On the suggestion of E. Baur, J. Lipski has hence tried, in the Brunswick Technical College, the compounds of the rare earths, with a certain amount of success. The way in which he proceeds does not look simple. But we remember that after years of failures, the preparation of incandescent mantles for lamps became an important industry, and that the rare earths are now obtainable in quantities which their name hardly justifies. Utilization of the rare earths is a very different thing at present from what it was twenty years ago. In preparing the cerium nitride, Lipski started either from the metal cerium, which the Elektrochemische Werke Bitterfeld supplied to him, or more frequently from the dioxide of cerium, which he treated with magnesium metal in an atmosphere of nitrogen. The metal cerium is steel gray, and can be turned, but is inclined to spark; the nitride is a black powder, which evolves ammonia in damp air; the hydride is a reddish or brown substance, which slowly ignites on exposure to air. These compounds were known, but Lipski has studied their dissociation pressures and reactions. He finds that at 200 deg. or 300 deg. Centigrade two reactions yield ammonia; hydrogen and cerium nitride give cerium hydride and ammonia; and nitrogen and cerium hydride yield cerium nitride and ammonia, so that the cerium serves in both cases as carrier to effect the combination of nitrogen and hydrogen; a third possible reaction, the re-liberation of nitrogen from cerium and hydrogen, does not take place to any noteworthy degree. Very small quantities of moisture and of oxygen interfere with the formation of ammonia, however; even in their absence, the catalysers become exhausted, after a certain time, but they recover. The cerium compounds need not be pure; the technical ceria is just as efficient as raw material. The ammonia percentage in the gas mixture did not exceed 6.4 per cent when using cerium nitride,

and 1.5 per cent when using the hydride. That would technically be sufficient if these yields could be maintained for long periods; the intimacy of the contact is of importance in this respect, of course. The full paper by Lipski may be found in the *Zeitschrift für Electrochemie*, April 1. In parenthesis it may be mentioned that this excellent German electrochemical journal is now being published as a semi-monthly. While chiefly devoted to the science of electrochemistry, it also brings now occasionally notes on industrial and commercial developments in electrochemistry in Europe. Dr. P. Askenasy, of the Institute of Technology of Karlsruhe, is the new editor.

ANALYSIS OF CURRENT ELECTROCHEMICAL PATENTS.

Reduction of Carbon Consumption in Carbide Production.—Mr. Remo Catani, one of the leading electrometallurgists of Italy and especially active in the electrometallurgy of iron and steel, has recently patented a process the object of which is to reduce the carbon consumption in the manufacture of carbides. The chief argument on which the process is based is that the fundamental reaction by which, for instance, calcium carbide is formed, is not $\text{CaO} + 3\text{C} = \text{CaC}_2 + \text{CO}$, as generally assumed, but $\text{CaO} + 2\text{C} = \text{CaC}_2 + \text{O}$. What really happens in the usual carbide furnace is the occurrence of the following three reactions in succession:



The first reaction takes place in the hottest part of the electric furnace, the second in a less hot part, and the third in a still less hot part. The object of Catani's process is to suppress the last two reactions. For this purpose he proportions the charge strictly according to the first reaction and coats the carbon in the charge with slaked lime, to prevent the second and third reactions. For calcium carbide manufacture he, therefore, uses a mixture of 24 parts by weight of carbon coated with slaked lime, and 56 parts by weight of calcium oxide—that is, 43 parts of carbon to 100 parts of lime are charged into the furnace. If the furnace is without electrodes or with electrodes of a substance not capable of being attacked by oxygen, the process may be applied directly, whereas when carbon electrodes are used or electrodes apt to be attacked by oxygen, they are coated with slaked lime, or an outlet is formed for the oxygen, keeping the tapping hole of melting furnaces open. The powerful pressure existing in the crucible of the furnace permits the oxygen to escape rapidly as soon as the outlet is opened, which may also be facilitated by suction. The same process may be applied to carborundum manufacture, the fundamental equation being $\text{SiO}_2 + \text{C} = \text{SiC} + \text{O}_2$, and to the manufacture of calcium cyanamide from the elements according to the equation $\text{CaO} + \text{C} + \text{N}_2 = \text{CaCN}_2 + \text{O}$. (918,419, April 13, 1909.)

Electric Furnace.—Mr. C. W. F. Gorrell patents an electric furnace for the fusion and reduction of oxide or sulphide ores. The ore itself forms the resistor and the current is passed through it by means of two electrodes. These electrodes are hollow metallic cylinder, water cooled in the inside, and provided with a carbon tip at the end. A hollow pipe passes through the center of the electrode, and the carbon tip at the end. Through this pipe carbon monoxide is blown into the fused ore mass, if the object is to reduce an oxide, or compressed air if a sulphide ore is treated. (916,548, March 30, 1909.)

Refractory Materials.—The manufacture of artificial emery from alumina, fused in the electric furnace, has made great progress in recent years in the hands of the Norton Co. A recent patent of Mr. A. C. Higgins refers to a method of obtaining a product of exceptional toughness and hardness by sudden cooling. The process is carried out in an electric arc furnace, Fig. 1. It has a movable hearth with a lining

of carbon, surrounded by a metallic trough or base-ring 3, which serves to collect the product. The shell or furnace casing 4 may be constructed of boiler plate or sheet iron, and is separable from the hearth, lugs 5 being provided for lifting it. Cooling or chilling of the product is effected by water supplied through perforated pipes 6 surrounding the upper portion of the shell. The perforations in pipe 6 are arranged to direct the water against the shell in such a manner that it flows down the inclined surface in an unconfined stream or film, to be collected by the base-ring 3 and discharged through a suitable waste pipe.

The aluminous material is continuously or intermittently fed to the crucible, and is fused therein by the heat of the arc or arcs, the crucible being in the meantime gradually lowered, as, for instance, by means of a direct plunger hy-

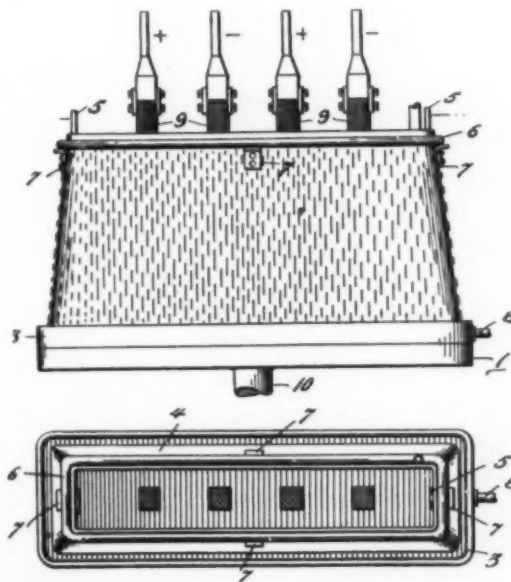


FIG. 1.—REFRACTORY MATERIAL FURNACE.

draulic elevator, the plunger of which is shown at 10. During this operation water is discharged, through the perforated pipes, against the shell or casing 4 in such manner as to cool or chill the molten mass in the crucible and to provide conditions under which the mass solidifies into an exceptionally tough and very hard pig, suitable for use in the manufacture of abrasives.

Since the chilling effect is of particular importance, it is preferable to construct the furnace in the form of a long and narrow chamber. (916,866, March 30, 1909.)

Silicon.—G. O. Seward and F. von Kugelgen recommend an arc furnace, without the use of any fluxes, for the production of silicon. The furnace is illustrated in Fig. 2. *B* is the carbon hearth, *J* the molten bath of reduced silicon. A 15,000-amp 30-volt arc is used with an electrode of 4 square feet cross-section. The charge is a coarsely ground mixture of flint rock and carbon, preferably merely crushing the flint rock to about 1-inch mesh size and grinding the coke so that it shall pass a 10-mesh screen. The mixture is kept piled about 18 inches above the lower end of the electrode, so that the arc is maintained in the midst of the mass of porous mixture. At starting a charge is made up of about 75 parts by weight of flint rock to 25 of coke, so as to introduce a surplus of silica, afterward changing this to 70 parts of flint rock to 30 of coke. There is no excess of carbon, or barely enough to maintain a reducing atmosphere around the incandescent zone of the arc. The temperature maintained under these conditions is above that at which silicon carbide remains stable, so that, even if this material is formed in part, it is immediately decomposed. The silicon is reduced in the form of vapor

and expands into the interstices of the porous mixture, where it condenses. These interstices being full of a reducing gas, namely, CO, allow the silicon to condense without being oxidized. The reduced silicon percolates down through the porous mass and collects at the bottom of the crucible. It is tapped out into carbon molds from time to time. A reduction zone is thereby maintained at a temperature so high that the sili-

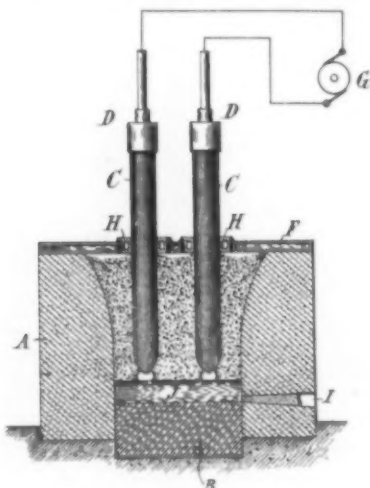


FIG. 2.—SILICON FURNACE.

con carbide cannot form or, if formed in part, is decomposed, and around this zone of reduction a cooler porous condensing zone, the interstices of which are kept filled with a reducing atmosphere which prevents the vapor of silicon from oxidizing before it can condense. (916,793, March 30, 1909.)

Electrolysis of Alkali Chlorides.—A combined mercury cathode and diaphragm cell is patented by J. J. Rink, of Copenhagen, Denmark. The construction is shown in Fig. 3, where *a* is a vessel of bell shape closed at the bottom by a porous diaphragm *b* of asbestos, stone ware, wood, etc. The platinum-iridium net *c*, a short distance above the diaphragm, is the anode. The receptacle *a* is surrounded by another vessel or tank *e* in such a manner that the diaphragm *b* is located at a short distance from a film or layer of mercury *f* which is spread over the bottom of the tank *e*. The space *g*, which is formed between the walls of the vessel *a* and the bottom and walls of the tank *e*, is connected by a horizontal tube *h* at its upper part and by a tube *h'* at its lower part with a concentration-vessel *i* in which the chloride to be treated, for instance, potassium chloride, is placed in solid form. In the tube *h'* is located a circulating-pump *h''* of any approved construction,

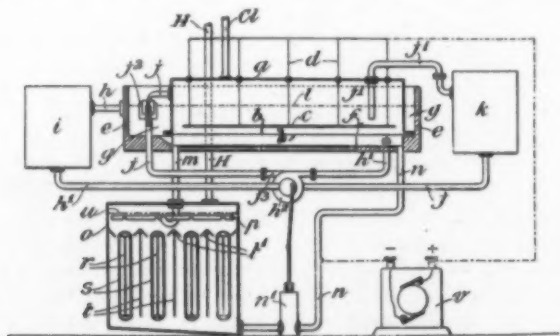


FIG. 3.—CHLORIDE ELECTROLYSIS CELL.

The space in the vessel *a* is in a similar manner connected by tubes *j* and *j'* with a second concentration-vessel *k*. The tubes *j* and *j'* are each provided with a mercury-seal *j''* for permitting the easy replacement of the same. The spaces in the bell-shaped vessel *a* and the tank *e* are filled up to a level with the line *l* with a chloride solution. The bottom of the tank *e* is covered

with the mercury-film and connected by two tubes *m* and *n* respectively with the upper part of a washing-box *O* and a mercury-pump *n'*. The tube *m* is tightly fitted into the top part of the box *O* and connected with a perforated horizontal distributing-tube *p* in the upper part of the box *O*. In the washing-box *O* are arranged wire-nettings *s* which are stretched around vertical plates *r* that are located directly under the openings of the distributing tube *p*. Between the wire-nettings *s* are located vertical metal plates *t* which are provided at their upper ends with inclined shedding-strips. The box *O* is filled with water or diluted lye up to a level with the line *u* and connected at its top part with a pipe *H* for the escape of the hydrogen gases. The bell-shaped vessel *a* is connected at its upper end with a conducting pipe *C'* for the escape of the chlorine gas. The solution which becomes gradually diluted by the deposition of alkali metal on the cathode *f*, passes from *g* through *h* in the upper part of the receptacle *i* and permits thereby the ingress (through *h'*) of a fresh quantity of a concentrated and pure solution or electrolyte. The solution which is contained in the vessel *a*, and which is gradually diluted by the separation of free chlorine on the anode *c* and by the passage of alkali metal ions through the diaphragm *b*, and which contains chlorine gas and some oxides of chlorine, is gradually forced out by the concentrated solution which is supplied through the tube *h'* and conducted through the pipe *j* into the concentrating receptacle *k*. Simultaneously the amalgam, that is to say, the mercury film *f* is moved in the direction from *n* to *m*. The amalgam which is discharged through the perforations of the pipe *p* drips over the wire nettings *s* and passes through the body of water to lye which fills up the space between the electro-negative plates *r* and *t*, and over the large surface of the latter, so that a quick and complete washing of the alkali metal is obtained. (918,370, April 13.)

Aluminium.—Mr. H. K. Blackmore patents a process which, by the first claim, is characterized as "the process of producing metal, which consists in exposing a substance, containing a metal and oxygen, capable of reacting with a carbide to yield metal, to electrolysis, while employing an anode containing calcium carbide." In the operation of the process he places in the receptacle a quantity of aluminium oxide and aluminium fluoride and fuses the same by passing an electric current between the carbon lining of the cast-iron receptacle and the calcium carbide electrode, having first started an electric arc between the same by placing them in contact and gradually separating them. He then feeds the aluminium oxide and aluminium fluoride in at intervals, as it fuses, and continues to add the mixture until the interior of the apparatus has been sufficiently filled; he then adds to the molten content a small quantity of calcium chloride to assist the fluidity of the mixture. "A reducing action is set up between the carbide contained in the electrode, such as calcium carbide, and the electro-negative constituents, fluorine and oxide supplied thereto, whereby they are removed, the fluorine combining with the calcium of the calcium carbide and the carbon liberated with the oxygen thereof, at the same time separating the metallic aluminium which accumulates in the bottom of the apparatus and is withdrawn from time to time through a tap-hole." The carbon oxide evolved from the anode escapes as gas. By supplying new anodes and fresh aluminium oxide and fluoride, from time to time, withdrawing the metal reduced and the accumulating fluorides, the process may be carried on continuously. (918,269, April 13, 1909.)

Plating Iron with Tin.—Hydrofluoric acid, first employed by A. G. Betts for lead refining and later recommended by E. F. Kern for various plating baths, appears to increase in favor with electroplaters. H. L. Hollis recommends an electrolyte of this kind for plating iron with tin. The electrolyte is prepared as follows: Seven parts by volume of hydrofluosilicic acid are added to 93 parts water and this solution is electrolyzed with an anode of tin and a cathode of iron. Tin is first dissolved at a higher rate from the anode than deposited

upon the cathode, but the rate of solution and the rate of deposition become gradually more equal; when the rates are the same, the solution is ready to be used as an electrolyte for tin plating. A small amount of gelatine or glue, added to the electrolyte, increases the density of the deposit. The same method may be used for zinc plating. (916,155, March 23, 1909.)

Nickel Electrode.—Mr. E. W. Jungner proposes a new method of making nickel electrodes for the nickel-iron accumulator. The nickel plate is suspended in a steel vessel filled with slaked lime which is kneaded to a stiff dough consisting of 100 parts of lime and 72 parts of a solution of caustic potash (6 grams of caustic per liter of water) to which are added a few cubic centimeters of ammonia of 0.85 specific gravity. A current of 5 amp per square centimeter is passed from the nickel as anode to the iron vessel as cathode for an hour. When the plate is taken out and the lime is removed, the plate is coated with an adhering layer of nickel hydrate, principally $\text{NiO} \cdot \text{H}_2\text{O}$. After about two hours charging with a current density of 1 amp per square centimeter in an electrolyte of 25 per cent alkali, the electrode is ready for use. (917,875, April 13, 1909.)

RECENT METALLURGICAL PATENTS.

Zinc.

Silicon as Reducing Agent.—Mr. A. G. Betts, the pioneer of electrolytic lead refining, is now directing his attention to zinc. His latest invention in this field contains nothing of an electrometallurgical nature, except the use of silicon as reducing agent, silicon being a product of the electric furnace. The process is stated to be especially applicable to zinc ores containing impurities, like iron or lead. The ore before or after roasting is mixed with silicon or a silicon alloy, as high-silicon ferrosilicon, in quantities sufficient to reduce the contained acids of zinc, copper, lead and iron, and the mixture is heated in a reverberatory furnace, but not to the temperature at which the reduction of zinc takes place. This heating can be safely done in the air or in the furnace gases without serious oxidation of the silicon. The heated mixture is passed into a highly heated furnace chamber, wherein the charge heats up further and the reaction commences and goes on. The heat of reaction is large and thereafter the amount of heat required to maintain the smelting temperature in a furnace chamber to which the ore and silicon mixture is added continuously or at intervals, while slags, etc., are tapped off, is largely reduced or entirely done away with. The distilled zinc is condensed with a suitable condenser. In distinction from the usual process, the presence of elements in the ore which yield liquid smelting-products is not disadvantageous, as any liquid products may be tapped from the furnace. The unoxidizability of the reducing agent used, except at very high temperatures, in distinction from the carbon hitherto used, allows of the ready and economical preheating of the charge by ordinary furnace methods. (918,648, April 20, 1909.)

Furnace Construction.

Roasting Furnace.—As much has been heard in recent years of the Wedge roasting furnace, a recent patent of Utey Wedge is interesting. Fig. 1 shows a vertical section of a five-floor furnace and a horizontal section along the line *a-a*. Annular roasting chambers 1 surround the revolving central shaft 2 with stirrer arms 10 with depending blades or rabblers 11. The stirrer arms 10 pass through the metallic shell of the hollow shaft 2 and are supported upon stuffing boxes 13. The ends of two opposite arms within the shaft are bolted together, so that each pair of arms constitutes a unit. Each of the arms 10 is hollow and has a longitudinal partition 14 extending part way through it in order to form passages 15 and 16 which communicate with each other through a common chamber 17 at the outer end of the arm. Both of the passages are continued into that portion of the arm which projects into the hollow shaft 2, the passage 16 being in free communication with the interior of said shaft, and the passage 15 communicating with a vertical

pipe 19 which extends to and through a diaphragm 20 located below the top of the shaft 2. The pipe of each arm, therefore, discharges into a chamber 21 contained within a casing 22 at the top of the shaft. This chamber discharges through a suitably sealed neck into a take-off pipe or stack 24. Through the pipe 30 at the bottom, a flow of air is induced by means of a steam jet 31 or the like. A constant supply of air is thus maintained within the hollow shaft 2, which can be maintained under

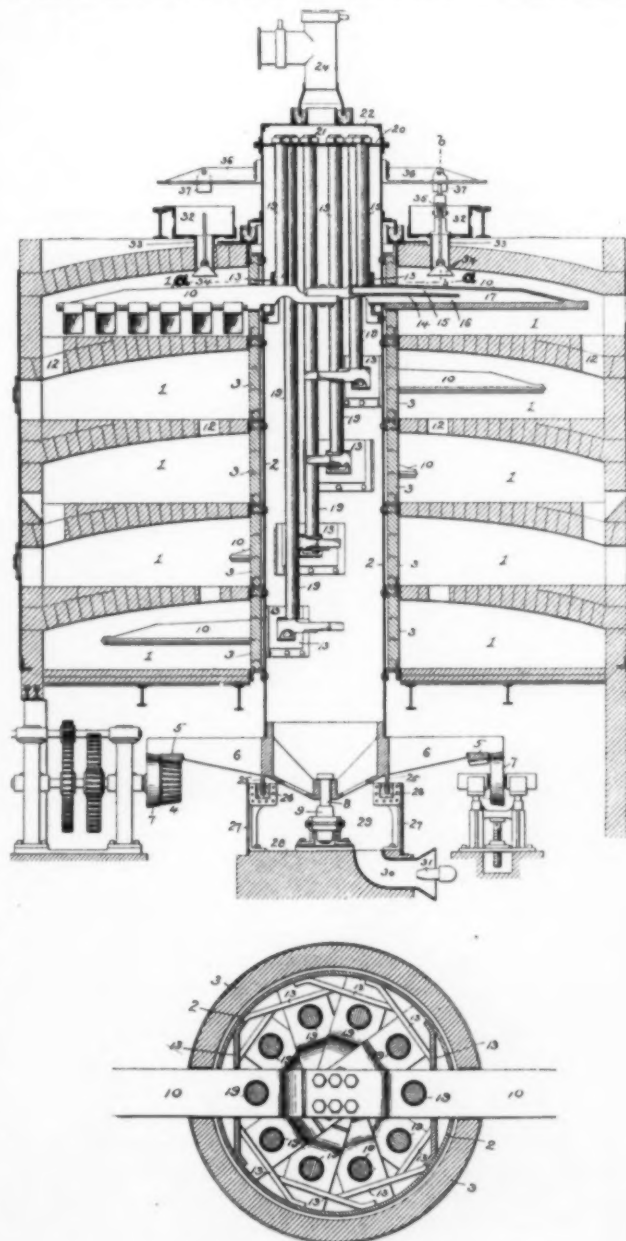


FIG. 1.—ROASTING FURNACE.

light pressure if desired. The air has free access to the inner ends of the passages 16 of the various stirrer arms, but can only escape from the passage 15 of each arm through its corresponding pipe 19. Consequently the circulation through each arm is entirely independent of the circulation through any other arm of the series, and is maintained under the same conditions as to all of the arms, so that the circulation must necessarily be uniform throughout the entire series of arms. When air is used as cooling medium, the heated air is taken out through the take-off pipe at the top of the shaft, and may be utilized. The material to be roasted is fed into the annular trough 32 at the top and then passes through necks 33 into the upper chamber of the furnace. (916,234, March 23, 1909.)

A Comparison Between Welding Systems.

The subject of autogenous welding—more particularly by means of the oxy-acetylene blowpipe—has now become of general interest to engineers, chemists, metallurgists and others, owing to the extreme flexibility of the process and the great variety in the nature and shape of the materials which can be successfully united by this means.

So far most of the articles which have hitherto been published have dealt almost exclusively with one or another from of apparatus, and but little has been written about the physical aspects of welding from a technical point of view.

Through the courtesy of the Linde Air Products Company, of Buffalo, we are now able to place before our readers some authoritative notes, for the most part based on some years' experience of the process, which have been compiled by Mr. K. S. Murray, and present the subject in a new and instructive manner.

In every process of welding, internal strains are inevitably set up. These are due to the fact that metal expands when heated and contracts when cooled, so that when two pieces of metal are welded together locally, either by simple fusion of the parts or with the addition of molten metal, contraction occurs as the metal cools. Where these parts form restrained members of any structure the internal strains produced are often sufficient to crack the metal.

This is more especially the case when welding is employed on hard, brittle or inelastic material, such as cast iron, and the tendency to fracture is greatly increased if the cooling of the metal after welding is conducted rapidly or irregularly. The magnitude of the forces which bring about this fracture in cast iron may be estimated by the rules for contraction which hold good in foundry practice, because in simple fusion-welding the physical conditions of expansion and contraction in and around the weld are not dissimilar to those of the foundry.

Whenever local strains exceed the strength of the metal a fracture must inevitably occur. These strains, however, often remain latent within the metal, so that the fracture may not actually take place until brought about by some external cause such as a light blow or even a current of cold air. The less brittle a metal naturally is, or, in other words, the more ductile it is, the better is it capable of withstanding internal strains of this description. The sudden cooling of any metallic body which has been welded should be scrupulously avoided.

In order to relieve a welded piece of metal from internal strains due to welding, it is desirable not only to pre-heat the whole of the part when possible, but also to re-heat it after welding to a cherry-red heat. This causes molecular rearrangement to take place within the metal, which will bring about a distribution, if not an actual dispersion of internal strains. In the case of cast iron this treatment is imperative where a repair is effected in a restrained member of the structure, and not only should pre-heating and re-heating (or annealing) be always employed, but the raising and lowering of temperature in so doing should be slow, and the casting should be kept entirely free from air draughts, or other extraneous cooling effects. This treatment is less essential for steel, but it can never be other than beneficial.

Unfortunately, for large work it is generally impossible to anneal the whole structure in this way. In such cases it is a useful makeshift to heat the plate for a considerable area round the weld, both before and after welding. It is obvious that the nearer the temperature of the whole structure can be brought to the fusion temperature required for a local repair, the less will be the excess of expansion at the welded point, and consequently the less will be the local strain set up at this point when the structure cools. Too much attention cannot be paid to this physical aspect of welding, and even when the process of fusion-welding is employed to fill up flaws in castings, it is desirable when possible to heat the whole structure before and after treatment.

The oxy-acetylene system of blowpipe welding is employed in two forms, which may be described as the high- and low-pressure systems.

The first to be introduced was the high-pressure system, in which both gases are delivered to the blowpipe under pressure. Oxygen is supplied from an ordinary trade cylinder and acetylene from a cylinder in which it is dissolved in a porous material soaked in acetone. Acetone is a liquid hydro-carbon which has the property of absorbing 25 times its own volume of acetylene at atmospheric pressure, and it continues to do this for every atmosphere of pressure that is applied to the gas. It was soon found, however, that the cost of using dissolved acetylene in this way was so high as to be almost prohibitive, except under special conditions, and the high-pressure acetylene generator was then evolved, to take the place of the tank of acetylene.

Of the two systems the low-pressure system of welding has undoubtedly been most generally adopted and is now gradually superseding the older system. In the low-pressure method only the oxygen is required under pressure. Acetylene may be taken from an ordinary generator of approved design. The size of the acetylene generator employed is, however, a matter of much importance in relation to oxy-acetylene welding. It may be taken as a general axiom with regard to acetylene that the more rapidly heat is generated during decomposition of the carbide, the more impure will be the acetylene produced and the worse the welding which will be effected with the gas.

If the decomposition of the carbide is effected with a restricted quantity of water, the heat evolved at the actual point of decomposition is so great that the acetylene itself becomes disassociated and re-forms into various hydrocarbons, which, when once formed, cannot afterward be eliminated without loss of acetylene. Furthermore, these hydrocarbons require more oxygen for their proper combustion than does acetylene, and consequently when they arrive at the blowpipe, then the proportion of oxygen which is correct for the proper combustion of acetylene becomes insufficient for the complete combustion of other hydrocarbons. On the other hand, if decomposition is slow, these difficulties do not arise.

A generator of adequate proportions, together with a holder of ample size for the gas consumption required, is, therefore, a most important desideratum in the selection of an acetylene plant for oxy-acetylene welding. The generation of acetylene should be both slow and regular.

In a properly proportioned welding equipment decomposition of the carbide takes place in such an excess of water that the heat evolved under ordinary working conditions is never sufficient to cause the above trouble.

The illustration (p. 227) shows a complete low-pressure welding installation of this type. The acetylene generator is entirely automatic, the absence of any positive feed mechanism being of great advantage. No motive power of any kind is required to operate the plant.

The temperature of the flame in a good oxy-acetylene blowpipe is approximately 6000° Fahr. This high temperature is mainly brought about by the combustion of carbon to carbon-dioxide. The chemical combustion of acetylene and the physical conditions which arise during its combustion in oxygen differ essentially from those which occur in the case of hydrogen.

Acetylene has a heating value of about 1500 B.t.u. per cubic foot. It is approximately composed of 92.5 per cent carbon and 7.5 per cent hydrogen, which in combustion with oxygen form carbon-dioxide and water. In consequence of the high flame temperature, however, the water formed by this primary combustion is dissociated into hydrogen and oxygen, the latter element combines at once in the flame with the carbon of the acetylene to form carbon-dioxide, while the hydrogen can only combine with oxygen which has passed out to the hottest zone of the flame, and thus does not involve a consumption of heat at the expense of the hottest part.

It is, in fact, claimed for oxy-acetylene welding that the hydrogen forms a relatively cool jacket round the hot flame produced by the combustion of carbon in oxygen, and that as the hydrogen is not able to combine with oxygen at the very high temperature which exists within the inner zone, but remains temporarily in a free state, it protects the inner zone in a measure from loss of heat, while largely excluding the tendency to oxidation of the metal—a defect from which all other methods of welding suffer. With the oxy-acetylene flame it is even claimed that burned or overheated metal is not likely to exist, because oxidized metal is not stable at such high temperatures and must, therefore, be reduced to a metallic condition.

The strength of the weld produced by the flame is almost invariably somewhat less than that of the original material. This may be due to the use of welding strips of inferior tensile strength, or to those internal strains which have already been referred to. It is also undeniable that the structure of the material in the weld is less homogeneous than in other parts. This, however, is largely a matter of skill on the part of the individual welder. It is possible for a competent welder, at his discretion, to give a greater or less strength to the welded part, and for this reason it is impossible to draw conclusions from the work of one man as to the work of another.

Oxy-acetylene welding must be regarded as a trade which can only be mastered by intelligent work and gradual development from simple to difficult jobs. Much depends on the intelligence and ability of the workman. A skilful welder will use a hammer freely as well as a blowpipe, more especially on vertical or overhead welds in plates which are subsequently to be subjected to pressure strains. By the judicious use of hammering at the right moment on the welded part, the metal can always be made denser, with the result that the strength of the weld is increased.

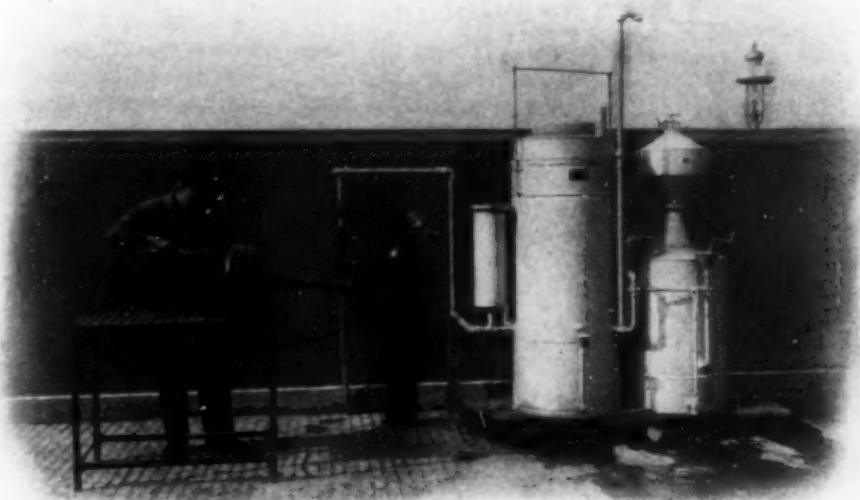
When the **oxy-hydrogen** flame is used for welding purposes the oxygen and hydrogen are generally produced by the electrolysis of water. Therefore their combustion may be described as the last stage in the cycle of change which the water has undergone. Hydrogen and oxygen have a strong affinity for each other, and their combination occurs with great explosive violence, the product being water in the form of steam. This steam is, of course, superheated in the hot zone of the flame and as steam is not stable at high temperatures it is bound to be re-decomposed into its elements in the flame. This decomposition or disassociation will begin at a temperature below 2000° Fahr., and continue with progressive violence until the temperature has reached 4500° Fahr., above which temperature the existence of steam as such in the hot zone of the flame is altogether impossible.

The process of dissociation involves a consumption of heat which is abstracted from the flame itself, and it leads to the existence of free oxygen in the flame, with consequently an oxidizing effect on the weld. This can only be avoided by feeding into the flame a large excess of hydrogen (in practice from four to five volumes of hydrogen to one volume of oxygen), while, on the other hand, only the amount of heat can be obtained which is disengaged by the combination of two volumes of hydrogen with one volume of oxygen.

The large excess of hydrogen required to prevent oxidation furnishes in itself one reason why welding by means of the oxy-hydrogen flame is frequently uneconomical. A further reason, however, lies in the fact that the temperature of the flame, in consequence of this, is essentially lower than it ought to be. Materials to be welded are usually good conductors of heat, and as the local heating of the body to be welded is a physical process which requires a certain amount of time, the quantity of heat lost by conduction in a body of the metal will be obviously all the greater the lower the temperature of the flame.

Hydrogen in combustion yields heat to the amount of 350 B.t.u. per cubic foot, but as at least four volumes of hydrogen must be employed with every volume of oxygen, for welding purposes, the true calorific value per cubic foot is about 175 B.t.u. as compared with 1500 B.t.u. in the case of acetylene.

In this country oxy-hydrogen welding has never been



WELDING WITH THE OXY-ACETYLENE FLAME.

employed to any appreciable extent. On the Continent of Europe, however, it has been in extensive use for a number of years. The process grew out of the introduction of electrolytic plants for separating oxygen and hydrogen from water. It became necessary to find an outlet for the hydrogen produced by this process in order to be able to sell oxygen at remunerative prices, and the oxy-hydrogen process resulted from this.

The introduction of the oxy-acetylene welding process in more recent years has not only checked the development of the older process, but, in fact, to a very large extent has entirely superseded it.

Another very important factor which militates against the successful development of oxy-hydrogen welding is the quality of the oxygen. It is practically impossible to provide against the presence of a varying percentage of hydrogen in electrolytic oxygen and an element of danger is thus introduced which does not exist in the case of oxygen produced by other means.

It has been stated that **electric welding** is more efficient and economical for most purposes than oxy-acetylene welding. This is, however, not strictly correct. The first cost of an electric-welding apparatus is incomparably greater than that of an oxy-acetylene welding apparatus. It is also far less portable, and its scope is consequently more restricted. There are certain applications for which electric welding may be more suitable, but for ordinary every-day work there can be no doubt that the oxy-acetylene system is much to be preferred for the following reasons, apart from the question of cost:

In welding with the electric arc heat must of necessity be concentrated upon one point, viz.: that to which the temperature of the arc is imparted. In oxy-acetylene welding, on the other hand, the heat can be brought to bear at will on the surrounding material. The correct welding temperature can thus be gradually attained at any desired point.

In electric welding any unsteadiness of the hand will at once strike the arc between the two carbon points, and will thus cause an addition of fused material to the bulk of metal where it is not required. In the oxy-acetylene process material can be gradually built up as desired exactly on the part to which the flame is being directed.

In electric welding the arc is formed at the expense of atmospheric oxygen, and this fact indicates that chemical changes of an oxidizing character must take place in the welding part. In oxy-acetylene welding, as already stated, the welded part is surrounded by a shield of hydrogen, which tends to isolate atmospheric oxygen from the part being welded.

In electric welding a fairly stout iron wire must of necessity be used to serve as a pole of the electric arc, whereas in oxy-acetylene welding thin wires can be employed, and these are found by experience to be most suitable for the work.

In electric welding the size of the drop of fused metal added in building up the weld is not within the control of the welder to anything like the extent it is in the case of the oxy-acetylene welder.

Finally—and this is perhaps the most important point of all—in electric welding any subsequent treatment of the welded place, such as gradual annealing of the area surrounding the weld, is impossible. In oxy-acetylene welding this can be done with ease and, as already pointed out, it is just this subsequent treatment of the welded part with a view to removing internal strains and depriving the weld of its hard and brittle character, which forms the special merit of oxy-acetylene welding in large and restrained structures, such as boiler flues and similar apparatus where homogeneity of the metal is a matter of utmost importance.

As illustrating the relative efficiency of oxy-acetylene and electric welding it is of interest here to quote tests published by Mr. Ruck-Keene, the principal engineer surveyor of Lloyds, in an instructive paper read by him before the members of the Institute of Marine Engineers on Sept. 28, 1907. The material operated upon was in each case the same, and it is important to note that while in the case of electric welding the ultimate tensile strength is somewhat greater than that obtained by oxy-acetylene welding, the ductility of the metal in the latter case is considerably better. The tests are, however, of chief importance as indicating the value of annealing.

OXY-ACETYLENE WELDING

	Breadth	Thick- ness	Area	Tons Total	Tons per Sq. In.	Extension in 4 Ins. per Cent.
	Inches	Inches	Inches			
Not annealed.	1.5	.62	.93	22.85	24.5	30 } Solid plate.
Annealed.....	1.5	.62	.93	22.35	24.0	36 } Extension in 8
						Ins. per Cent.
Not annealed.	1.5	.62	.93	22.9	24.6	28 } Broke away
Annealed.....	1.5	.62	.945	22.1	23.3	20 } from the weld

COLD BENDS

Not annealed.....	180°
Annealed.....	180°

ELECTRIC WELDING

	Breadth	Thick- ness	Area	Tons Total	Tons per Sq. In.	Extension in 4 Ins. per Cent.
	Inches					
Not annealed.	1.0	.56	.56	15.35	27.4	12 } Broke
Annealed.....	1.0	.55	.55	14.5	26.3	14 } through weld.

COLD BENDS

Not annealed (showed signs of fracture at weld).....	58°
Annealed.....	100°

Increasing the Efficiency of Plate Amalgamation by Electrochemical Action.

By ELMER ELLSWORTH CAREY.

Within the last decade the problem of using electricity in a practical and efficient manner in the extraction of metals has received the earnest attention of many investigators.

One of the first applications of electrochemistry to the modern metallurgy of gold was the electrolytic precipitation of gold from cyanide solutions.

Turning to amalgamating practice, it may be said that electrochemical methods may now be successfully used in connection with the usual battery plate. After a long series of experiments, extending over a score of years, a very simple method of converting the standard plate into an electrochemical amalgamating device of remarkable efficiency has been devised. The electrochemical system of amalgamation is designed to extract from the sands or pulp all gold values not encased; it is an entirely new system of amalgamation, designed to do the work of the ordinary mill plate, including the treatment of slimes, and at the same time to extract values which cannot be saved by the usual mill practice and which otherwise would require cyanide treatment; to do all this in one single, inexpensive and continuous operation, requiring practically no more outlay for installation and maintenance than the usual mill plate.

The system also furnishes a method by which the Alaska beach deposits, black sands, hydraulic placer and dredge tailings, mill tailings, desert deposits and many low-grade propositions can all be profitably worked. The broad claim made for the electrolytic system is that it will save all values not encased.

Preliminary Treatment.—It may be sometimes necessary to grind ore or sands to 100, 150 or even 200 mesh, before the values are released, but after this has been done the pulp is simply passed over the amalgamating device, by which, with the aid of electrochemical action, the gold is extracted to such an extent that usually no further treatment is profitable. In ordinary cases, values are recovered at 80 mesh. In certain cases where the ore is unusually refractory, base or rebellions, it may be necessary to treat the tailings for an hour or two by the continuous electro-cyanide process, which is an exceedingly simple and inexpensive operation, but withal very efficient.

Apparatus.—This method of gold recovery calls for a sluice box of suitable width, the length being 40 or 50 ft., or even longer, according to conditions. In the bottom of the box is an ordinary copper plate acting as a cathode. Graphite anodes are employed. Direct current of low voltage is used, passing from the graphite anodes through the solution to the amalgamating device and the copper cathode plate. Pulp of proper fineness, screened gravel or sand is passed into the device.

Essential Elements of the System.—The anodes and cathodes are connected with a generator in the usual manner, the voltmeter, rheostat and ammeter being in place. The current density is approximately one ampere per square foot of cathode surface.

In operating the mercuric salt solution is mixed with the water passing into the device. The amount of the solution, which is standardized, depends upon the values in the pulp. Several reactions are simultaneously going on, of which we will now mention the more important ones.

Deposition of Mercury.—There is a constant and uniform deposition of "virgin" (nascent) mercury on the cathode plate, so that the cathode plate is covered with a bright, shining and chemically pure coating of mercury, which remains in a perfectly "healthy" state as long as working conditions continue. The deposition of mercury and the character of the amalgam are at all times under absolute control of the operator. The mercury coating or plating adheres tenaciously to the copper plate, and the passing volumes of water, sand, pulp, etc., have no effect upon it. When no gold is present in the gangue after

a certain amount of mercury has been deposited, no more mercury will adhere, but any excess will collect in globules and be carried over the plate, which is amply provided with mercury traps at the lower end. But with proper adjustment, no excess of mercury is possible, and no "floured" mercury is discernible in panning the tails. This coating or plating of mercury above mentioned will stand the action of a heavy volume of running water containing a full load of pulp; even water carrying a full load of magnetic iron has no injurious effect on it.

Mercury deposited by the electrolytic action withstands the erosive action of a heavy volume of water (200 gallons per minute and black sand containing 66 per cent iron; at one time 40 tons of black sand were used to test this matter, and the fact is as above stated.

By continually reproducing the mercury cathode surface by electrolytic deposition its amalgam-forming powers are intensified to such a degree that rusty, greasy or pyritic gold is instantly amalgamated; platinum is absorbed as quickly as gold when sodium is present in the amalgam (see below under sodium amalgam). Grease, talc, silicious coatings or sulphurous conditions in connection with gold particles have no effect in preventing amalgamation, and "fouling" or "sickening" of the plate is impossible. The use of electrolytic amalgamation insures a constantly bright, healthful and powerfully active mercurial surface, impossible under the usual practice. The behavior of the mercury under electrolytic conditions is entirely different from its action in ordinary amalgamating practice; and conclusions based on the usual behavior of mercury will not apply in the new method.

"Nascent" Hydrogen.—Hydrogen at the moment of its liberation from a compound is often called nascent hydrogen, and is in this condition very effective as a reducing agent; it destroys instantly organic, greasy and foul conditions; it unites instantly with the oxygen of iron rust at ordinary temperatures, thus cleaning "rusty" gold, and the action of nascent hydrogen on the mercury is such that fouling of the plates cannot occur.

The action of nascent hydrogen as a cleanser and reducing agent is used to advantage in the electrochemical amalgamator, and if the gold particles are unusually coated or rusty additional volumes of hydrogen can be obtained through electrolysis by adding some inexpensive solution of a potassium or sodium salt. Under the action of electrolysis the mercury as fast as deposited absorbs free hydrogen, which is occluded throughout the whole mass of mercury; and the gas is all the time exercising a powerful cleansing and reducing effect and preparing the way for amalgamation. Under these conditions mercury is in the best possible condition to form amalgams.

Formation of Sodium Amalgam.—When sea water is used in the electrolytic system of amalgamation, or when a solution of common salt, or some solution containing a sodium salt, is mixed with the water entering the device, we have also the deposition of metallic sodium, which alloys with the mercury, and a sodium amalgam is formed. Sodium amalgam will hold free gold in any condition; also platinum; at least hydrogen sodium amalgam will amalgamate all metals not encased, which are in a comminuted state, and sodium amalgam by electrolysis cannot be made without the presence of hydrogen.

Hydrogen Sodium Amalgam.—In Vol. I, *Proceedings of the (London) Inst. Min. and Met.*, page 205, P. G. Warnford Lock describes the formation of hydrogen-sodium amalgam and mentions the powerful affinity between this amalgam and gold. In electrolytic amalgamation the hydrogen is formed in several ways. Part of the hydrogen liberated forms hydrogen-sodium amalgam, and part is used in reducing oxides, which form rusty coverings on gold particles; parts also act as a general cleanser and purifier as it escapes through the water.

Formation of Gold Amalgam.—We have seen above how

the presence of hydrogen and sodium prepares the way for amalgamation. So well has the work been done that amalgamation takes place as soon as a particle of gold touches the quickened mercurial surface. And it might be noted in passing that amalgam formed under the conditions which we have described (electrolytic amalgamation) is a different compound from the usual amalgam formed on mill plate. The amalgam as described holds to the plate very tenaciously and is not easily dislodged. It is homogeneous and free from foreign materials. Particles of amalgam under this system are not broken off by the passing volumes of water.

The larger particles of gold will come in contact with the mercury before passing many feet; microscopic values or float gold, or values in slimes, will require a longer length of cathode surface; at times possibly 40, 50 or even 60 ft. will be required, but any microscopic particles, or any of the values in slimes will be instantly arrested at the first contact with the mercurial surface. Experiment has demonstrated that electrolytic amalgamation will recover from 95 to 99 per cent of all gold not encased. When pulp is ground to 100 or 200 mesh, the tailings after passing the electric amalgamator do not contain enough values to make any form of supplementary gold devices necessary.

Chlorine Gas.—Nascent chlorine is liberated at the anode when common salt or other chlorides are electrolyzed in solution. The chlorine dissolves in the water. Water saturated with chlorine and the further chlorine compounds which may be found have a bleaching and cleaning effect.

Electrolysis of H₂O.—The decomposition of water has been mentioned with the evolution of free hydrogen at the cathode. At the anode oxygen is liberated, which also assists in preparing values for amalgamation, as it is a powerful enemy of organic substances, and foul, greasy or dirty conditions are quickly eradicated by its action.

Mechanical Action of Gases.—At all times there are liberated from every portion of the surface of the cathode free gases, which rise upward through the water. These constantly escaping gases have a tendency to act as a cushion over the newly formed amalgam, which cushion prevents in a measure any scouring effect on the part of both sand or gravel, thus rendering the system equally applicable to stamp mills, placer mines, gold dredges and beach mining. Gravel and black sand can be passed over the device and freed from all values, no matter how small, which may be present.

"Dynamic Electrical Action."—The claim is made by the inventor of this system that "a critical electrical current when properly adjusted tends to force all gold particles to the cathode plate, and that such current actually does carry microscopic particles into contact with the mercury; and that the efficiency of this force depends upon density, voltage and proper adjustment of the device." There is considerable evidence to support this contention that there is a dynamic action in the electrical current that carries gold particles to the cathode. As a rule, all values are deposited in the mercury in the first 10 or 12 ft. of plates; and it is hardly reasonable to suppose that gravity alone would be sufficient to force every particle of gold into an amalgamating contact in such a volume of water as is used. If the necessary contact for amalgamation was the result of chance and gravity, it would be reasonable to look for an occasional color in the tailings; but not only is it impossible to find a color there by the most careful pannings, but it is impossible to find any value of importance by the most careful assay.

Conclusion.—In the system of gold extraction above outlined, amalgamation proceeds under the most favorable conditions that can be provided. Every obstacle is removed, and every force that tends to assist is intensified and reinforced. Not in a laboratory could a more positive action be obtained. Instead of leaving the amalgamating process to chance and the uncertainties of the usual practice, with all attendant difficulties,

we have in the process in question the formation of amalgam carried on under ideal conditions, where the highest possible efficiency is attained; and it should be remembered that the processes and forces which deposit the mercury and gold in the form of amalgam are constantly striving to hold the amalgam in place, and to resist any erosive tendencies of the water and pulp. In view of these facts, it is not unreasonable to hope that electrolytic amalgamation may come into extended use, and at the same time vast fields be opened for the miner which are now beyond his means.

The only special machinery required for the electrolytic system of amalgamation is a low-voltage generator, requiring from $2\frac{1}{2}$ to 5 hp for operation. A 5-hp generator will furnish sufficient current for the treatment of 500 tons daily.

San Jose, Cal.

Thermit Welding on the Pacific Coast.

The thermit process, the principles and general applications of which are so well known to our readers, is constantly being called upon for repairs which are decidedly out of the ordinary. That is one reason why the process is so interesting to follow and why those who once adopt it become so enthusiastic over it. Two repairs carried out by the Pacific Coast branch of the Goldschmidt Thermit Company, of New York City, may be described.

An instance occurred last December, in San Francisco, which

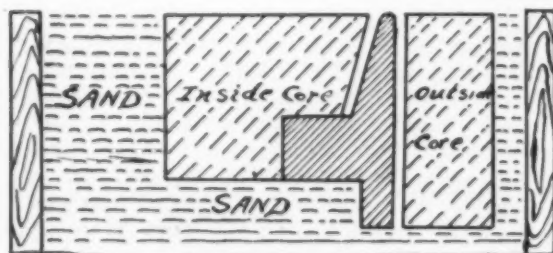


FIG. 1a.—CROSS-SECTION THROUGH MOLD AND RING, SHOWING ARRANGEMENT OF CORES.

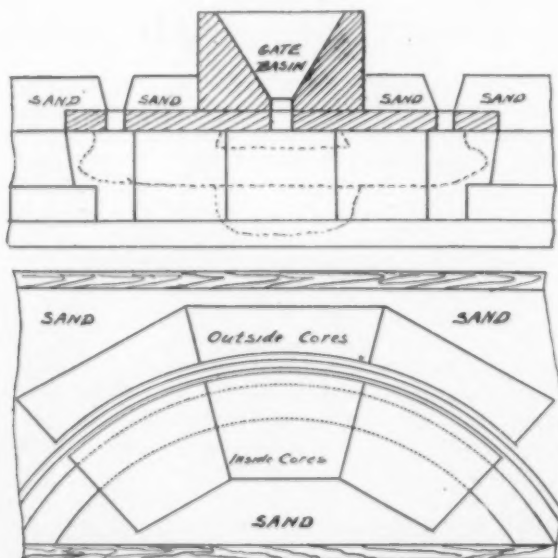


FIG. 1b.—TOP VIEW AND LONGITUDINAL SECTION.

(Dotted lines show where metal was cut away, preliminary to welding.)

is certainly different from any thermit repair heretofore attempted. It was found that the end of a commutator ring was frozen into the copper commutator of a large generator belonging to the San Francisco Gas & Electric Company. A good deal

of the copper had formed a very hard alloy on the surface of the ring, and it was necessary to cut out 24 in. of the circumference, as shown in Fig. 1, and weld in a section of thermit steel to replace that cut away.

The difficulties to be encountered in making such a weld, made the job appear a desperate one, but owing to the fact that the generator was very badly needed, it was resolved to undertake the repair.

It was impossible to use the wax method, described in this journal, Vol. VI, p. 166, in this case, as there was no compressed

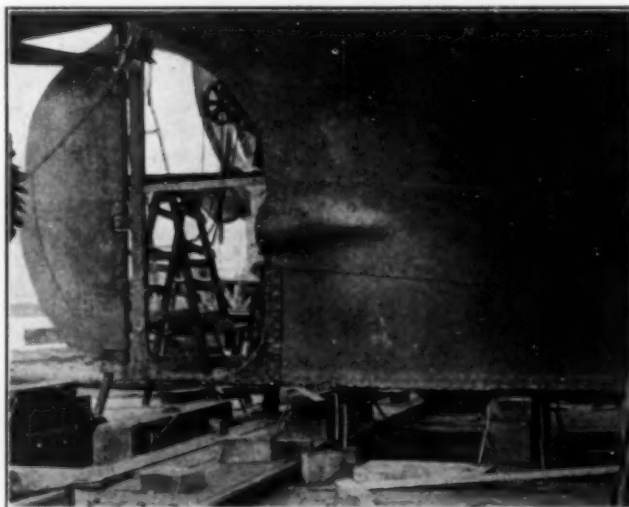


FIG. 2.—STERN FRAME TO BE REPAIRED.

air available. Furthermore, it would have been extremely difficult in any case to hold so much wax (a section 24 in. long) in position against the tamping. It was decided, therefore, to make cores both for the inside and outside of the mold by building corresponding boxes of wood and using a good part of the ring as a pattern, extra space being allowed for subsequent finishing off. This extra space was gained on the inside by some flat pieces of rubber which were at hand, and for the outside a heavy sheet of asbestos was used, covering the face of the ring. Three cores in all for the inside and an equal number for the outside were required. The top was covered by cake cores and basins were formed for the running gate and for the overflow to the risers—one at each end.

The heating was done by removing these cake cores, which exposed the metal of the ring to the direct flame of the torch. When the surfaces had been brought to the proper temperature the torch was removed, the cake cores replaced and the thermit steel tapped into the mold. Ninety pounds of Thermit, 12 lb. of punchings, 3 lb. of borings, and $12\frac{1}{2}$ oz. of pure manganese were required for the weld.

The metal obtained was very good and tough and of medium-fine grain. About an hour after the pour the mold was dismantled and the ring sent to a nearby machine shop to be finished. The finishing showed that good fusion had taken place between the thermit steel and the steel of the ring and the repair was, therefore, a success.

Another interesting repair carried out recently on the Pacific Coast by the thermit process was the welding of a new skeg in the stern frame of the United States Quartermaster steamer *General McDowell*. This is a steel vessel of 160 gross tons, built in 1886 by the Union Iron Works, of San Francisco. Her dimensions are as follows: length, 125 ft.; beam, 23 ft., and depth, 10 ft. 6 in.

The operation consisted in cutting out the old skeg and replacing the same with a new piece, the welding of this new piece having been ordered by the Government authorities at Washington to be performed by the thermit process. Fig. 2 is a general view of the stern frame of the steamer, giving a good idea

of how badly worn the old skeg was. To strengthen it, an iron shoe had formerly been fitted and riveted to the skeg, and the holes seen in the picture are the rivet holes used for this pur-

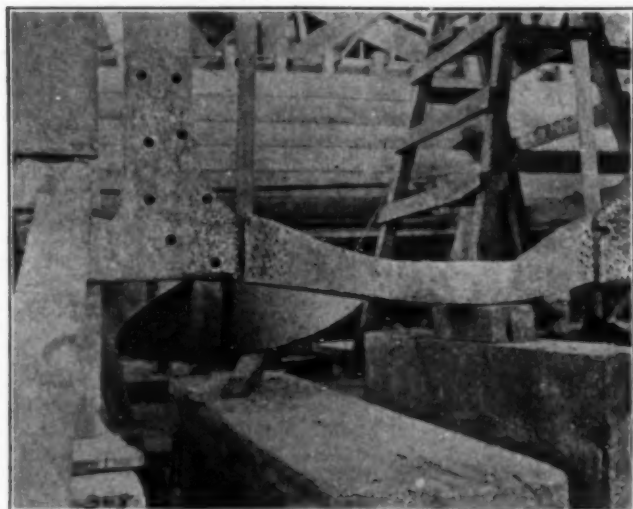


FIG. 3.—NEW SKEG PUT IN PLACE.

pose. Fig. 3 shows the new skeg, just having been put in place before having been properly supported or secured. It also shows the space on each end of the skeg between the old work and the new.

The new skeg was first forged of iron to the proper shape and placed in position, so that grooves cut fore and aft corresponded to similar grooves in the ends of the stern frame. The object of these grooves was two-fold: first, to form a key for the thermit metal, and, secondly, to hold a gib, in order that the skeg might be secured in place temporarily while the mold was being rammed up. A common mold box for the two welds was constructed and a wax pattern formed around both ends of the skeg. When this had been completed, the gibs above mentioned were withdrawn with great care and the ramming of the mold completed. This work required one day for its completion and the next day the actual welding was undertaken.

As in the case of the commutator ring, it was necessary to

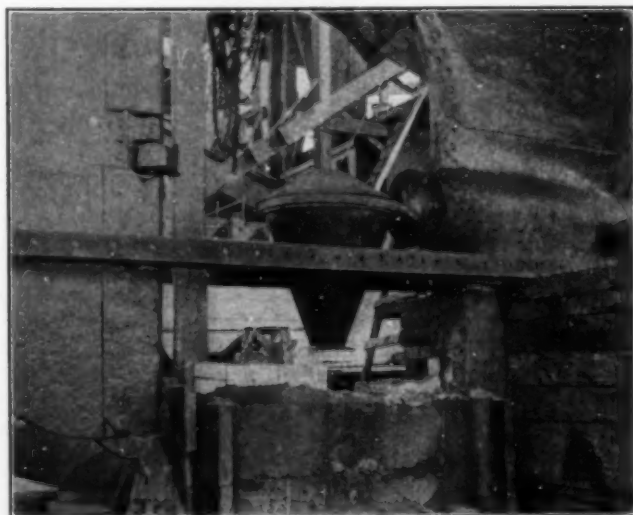


FIG. 4.—VIEW AFTER COMPLETION OF SECOND WELD.

preheat these sections before pouring in the thermit steel and a gasoline torch was accordingly set going to accomplish this result. While the heating was in progress, the charge of ther-

mit for the first weld was placed in a crucible suspended over the pouring gate of the mold.

Altogether this weld required 184 lb. of thermit, 40 lb. of mild-steel punchings and 4 lb. of pure carbonless metallic manganese. When the sections had been brought to a red heat, the torch was withdrawn, the heating gate plugged up and the thermit ignited in the crucible. At the end of the thermit reaction the steel was tapped into the mold, where it filled the space previously occupied by the wax.

A second weld was made in the same manner and required 150 lb. of thermit, 30 lb. of punchings and 3 lb. of carbonless manganese.

Owing to the fact that there were two breaks, it was necessary to move the crucible and a very ingenious apparatus was constructed for this purpose. The crucible was placed in a little frame on wheels, which enabled it to be very easily shifted fore and aft and after the first weld was completed the crucible was not raised or lowered, but was simply moved bodily, with frame and supporting angle irons, from the starboard side of the ship to port, so as to be in proper position for the gate of the second weld.

Fig. 4 shows the condition of the work after completion of the second weld. It shows the box built around the whole

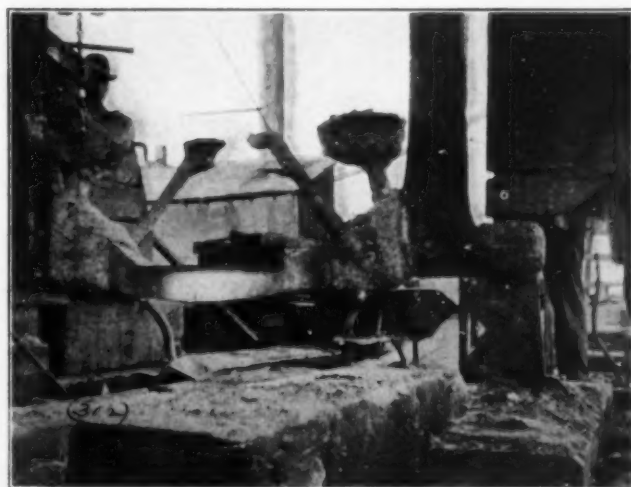


FIG. 5.—COMPLETED WELD WITH GATES AND RISERS.

length of the skeg. The fire brick on top of the mold formed a little wall built up and luted to prevent an overflow of slag from the first weld into the after mold. The picture shows the crucible supported on angle iron, and the protection of the stern sleeve by a plate against the spatter of thermit metal or slag. Above the crucible may be noticed the corner of an iron plate. These plates were secured under the counter of the vessel to protect it from the action of the crucible.

The day following the completion of the two welds the mold was dismantled. Fig. 5 shows the completed weld with gates and risers. The metal which had been left in the gates and risers was then removed and the welds were then tested by the chief engineer and found to be perfect.

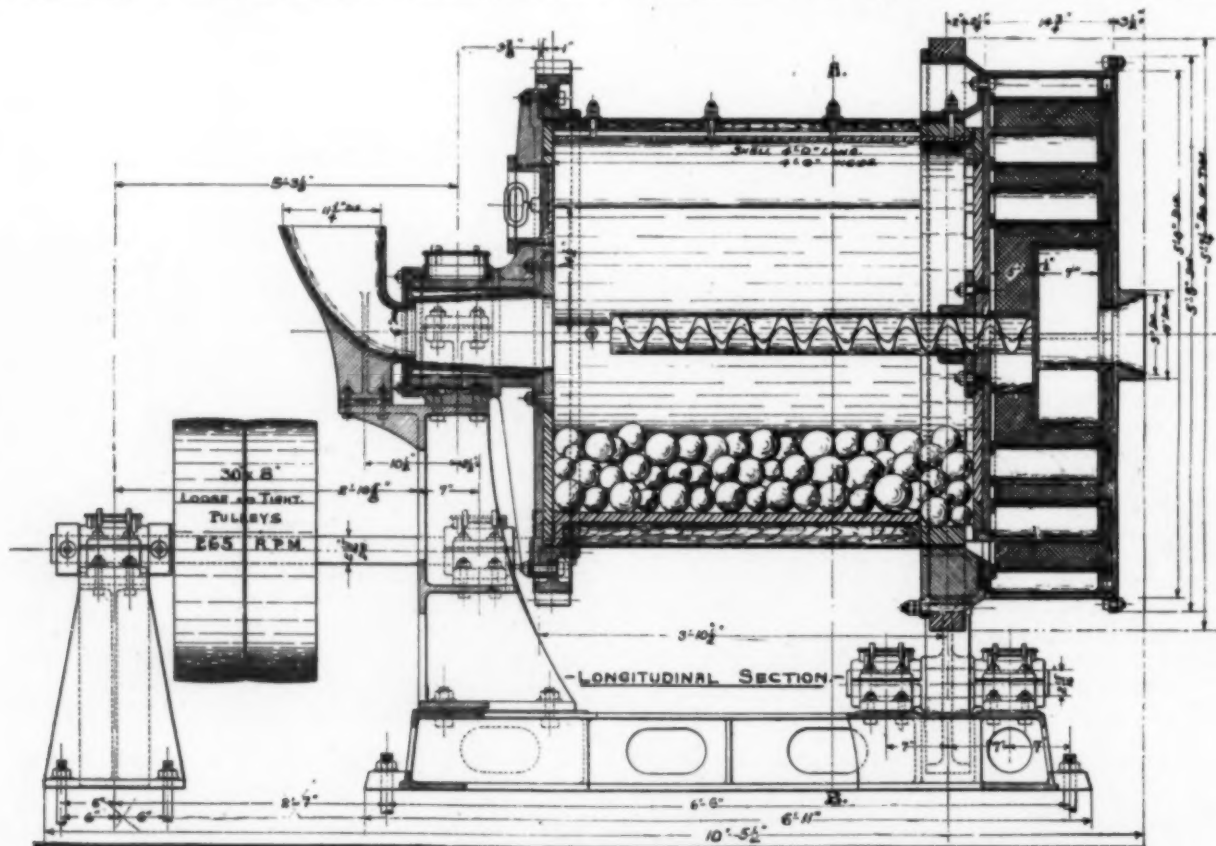
It might be pointed out here that had this repair been made by any other method it would have been necessary to remove the entire stern frame from the ship—an operation of considerable magnitude, as all the plates are riveted to the frame and would have had to be cut loose, after which the welds would have had to be made in the forge and the frame replaced. By utilizing the thermit process, however, such repairs as the above may be carried out in from two to three days and on their completion the vessel is ready to be placed in immediate service.

The Standardization of Refractory Materials.

In the (London) *Electrical Review* of March 19 we find the following notes, which should also be of interest to American users and makers of refractories:

An important movement has been set on foot at Stoke-on-Trent, under the auspices of the English Ceramic Society, having for its object the arrangement of an agreement between technical institutes and societies representing various important industries, for the grading and standardization of refractory materials, such as fireclay and magnesite, used in the construction of furnaces, kilns, ovens, etc. The importance of any advance in the direction of making refractory materials more resisting to high temperature has often been commented on; in Germany there exists a recognized center to which one can refer for unbiased reports as to the qualities of refractory materials,

To carry out this scheme it was agreed that the representatives of the institutes should consult with their respective fellow-members, and whenever possible procure information bearing on their specific requirements, together with data as to furnace temperatures and conditions of operation. Each section will at first conduct its own part of the inquiry independently of the others and prepare a draft of their own suggestions to be submitted to the next meeting of the general committee, which will be held in some center other than in the potteries, probably in London. These suggestions will be embodied in a provisional report to be sent back to the sections for approval or amendment and finally published as a general report. It is proposed to revise this report periodically to keep abreast of developments. Arrangements are being made in France, Germany and America to ensure that the method ultimately arrived at shall be international. The negotiations with America are already in



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FIG. 1.—SECTION OF BALL MILL.

but in Great Britain and in France research of this character is in a very backward condition.

Dr. J. W. Mellor, Staffordshire County instructor in pottery and honorary secretary of the English Ceramic Society, has now taken the lead in initiating a movement to deal with the subject, and as the result of a circular sent out a meeting was recently held at Stoke-on-Trent, at which there were present representatives of various industries from all parts of England.

As the result of the deliberations of the conference it was decided to form a body to be called "The Center for the Standardization of Refractory Materials" and the objects of the committee were embodied in the following preliminary program: (a) To arrange and classify the various refractory materials—clay, silicious, as silica and ganister; special, as magnesite, chromite, etc.; (b) to arrange standard specifications for the raw materials and for the manufactured products; (c) to consider the possibility of arranging for uniformity in certain "stock" or "standard" sizes, and (d) to agree upon standard methods of testing, analysis, etc.

an advanced stage. Dr. Mellor has been inundated with correspondence by manufacturers since the initiation of the movement, which will probably lead to a very great advance in the quality of the finished products.

Ball Mills.

Ball mills are very extensively used in various industries. By a peculiar looseness of expression, no sharp distinction is often made between ball mills and tube mills. It may, therefore, not be superfluous to emphasize that ball mills and tube mills are not only two different kinds of apparatus, but serve different purposes.

Ball mills are very extensively used for preparing material to be fed to tube mills. In mining ball mills are also extensively employed for preparing ore for concentrating purposes, taking the lump ore and reducing it to 30, 40, 50, 60, 70 or 80 mesh, etc.

In the following we give a description of the Abbé ball mill

built by the Abbé Engineering Company, of New York City. It consists of a grinding chamber containing steps, which are surrounded by the steel shell, which forms the mill proper. Between the steps and the shell there are wooden pieces which fit the shell exactly and also the form of the steps, thus making a cushion that releases the effect of the jar to a considerable extent.

Onto one end of the shell is bolted the head with the trunnion and on the other end the spiral discharge and spiral screening chamber. The material to be ground is fed to the mill by means of a regular table feed and enters the machine through a pipe fastened to the trunnion. In this pipe there is a spiral that conveys the product forward into the grinding chamber,

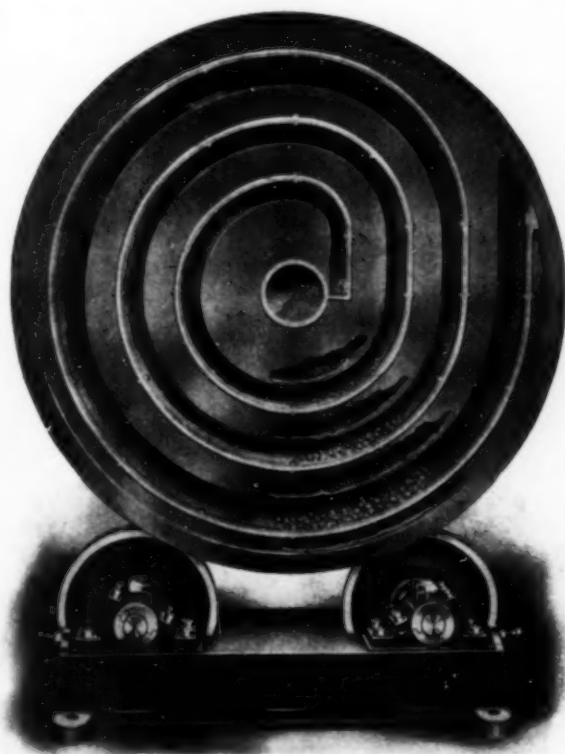


FIG. 2.—BALL MILL (SPIRAL SCREEN OPEN).

where it receives the grinding of the charge of balls while traveling the full length of the machine, so that a larger grinding capacity is obtained.

The rate at which the material is fed into the mill regulates the amount of grinding it receives and the fineness at which it reaches the screen. The faster it is fed the coarser it is discharged and the slower it is fed the longer it receives the action of the balls. The ground material leaves the grinding chamber through openings at the discharge end.

The material falls on the first turn of the screen and as the mill revolves the fine material drops through onto the discharge spiral, which conveys it to the center, where it is discharged, while the coarse particles are retained by the screen, which also forms a spiral between the spirals of the discharge, so that the tailings are carried to the center by the screen and are there returned to the grinding chamber for regrinding by a conveyor, which revolves with the mill inside.

The grinding steps in the Abbé ball mill are solid, rest on the wood above mentioned and the machine is so constructed that any one, or all of the steps, can be taken out without disturbing the entire structure of the machine, so that the lining steps can be worn down very thin before they have to be replaced.

The Abbé ball mill requires no high foundations above the floor line, as it is fed and also discharged at the center. This

means a saving of a great amount of money in the first cost of installation, makes it far more accessible from every point, and causes a saving in space which is sometimes very valuable.

The screening chamber, as built and attached to the Abbé ball mill can be made of ample capacity to handle any output that the mill will produce on different materials. It can be made larger in diameter or of greater width to accommodate the variations in the output when handling different materials.

Screening in the Utah Copper Company's Mill.

BY H. B. LOWDEN.

As originally designed and equipped the mill of the Utah Copper Company contained trommels as the main screening equipment, the undersize passing over stationary inclined screens. Each of the 12 units comprised four 48-in. x 144-in. trommels and two of the inclined flat screens, the trommels being clothed with rolled slot wire cloth equivalent to about six mesh and the stationary screens with similar material passing a product equal to about 20 mesh.

Shortly after the first units were placed in commission the usual difficulties in the operation of trommels made themselves felt and more efficient and economical screening equipment was sought; to which end a number of devices were systematically tried on a large working scale. The results of these tests were so conclusively favorable to the impact screen that it was determined to equip the twelfth unit, at that time nearing completion, with these screens and in it to demonstrate conclusively the adaptability of the machine for the work. The twelfth unit was operated with decidedly improved results, due to closer sizing, and with a capacity of 600 as against 500 tons per day of the other units owing to the tables being able to handle a greater tonnage of the more closely sized feed. The screens in this unit were running wet.

The work of replacing all the screens throughout the other units of the mill was then determined on, and has proceeded as rapidly as possible without undue interference with operations; sufficient time having now elapsed to permit of comparison between the two, the net result of the change can be summarized as follows:

The capacity of each unit has been increased from 500 tons to 600 tons per day, the tables handling the increased feed by reason of its closer sizing, and the rolls by being freed from a flood of undersize material which was formerly returned with the oversize for recrushing and which now passes through as finished product as it should. The saving of about one-quarter of the water used by the trommels, by running the four coarse impact screens, the crushing rolls and the elevator dry on the ore as it comes from the mine, this also increasing the life of the elevator from four months to eighteen months. The cost of screen cloth is in the ratio of \$128 for the trommels to \$14 for the impact screens.

Progress of Autogenous Welding.

BY AUGUSTINE DAVIS.

Encouraging progress is being made in autogenous welding by the oxy-acetylene process in the United States. Cast-iron kettles, weighing approximately five tons, have been most successfully repaired where the cracks were so large that from 50 to 100 lb. of added metal was required. The welding of cast-iron automobile cylinders and aluminium gear cases has quickly become a good business wherever repair plants have been established.

Several pipe-bending concerns have installed plants to great advantage and the process is particularly valuable in the manufacture of steel window sash and frames and doors and door frames. Seamless steel range boilers are now being made so extensively that they are driving the riveted boilers from the market. One of the largest car building companies is now using the process for steel car construction. The U. S. Navy

Department has purchased three plants for use in the Navy Yards and is performing much work of value.

While there is an almost unlimited field for the process in new construction, and new uses are being discovered almost daily, the immediate demand is for repair work of nearly every character and for reclaiming defective castings.

The greatest difficulty in repairing cast iron is to overcome expansion and contraction, but ingenuity and experience have made great advances in this respect.

The development of the apparatus itself in this country has outstripped France where the process originated. The Davis-Bournonville Co., 86 West Street, New York, has constructed at Marion Station, Jersey City, a building which is devoted exclusively to the development of the art and for the instruction of operators.

To be successful the supply of gases must be unfailing; the pressures uniform and adapted to the metal to be welded and the mixtures must be most accurately maintained so that the flame may be non-oxidizing and non-carbonizing, otherwise the metal will be burned or rendered brittle. It is also necessary to have the welding materials and other supplies of the highest quality in order to attain the greatest degree of success.

The welding torch is becoming widely known as a "putting-on tool" because worn parts can be restored and new parts actually built on.

With a flame that will quickly melt any metal, furnished by a torch that can be manipulated as readily as almost any hand tool, with a supply of gases either portable or stationary, not requiring a power plant of any kind during operation, there is presented to the seeker after reduced costs and improved methods of construction, a process scarcely limited by anything other than the ability of the operator himself.

A New Type of Pyrometer for Use in Furnace Work.

The vast majority of pyrometers used in factories are used primarily to tell the operator whether the temperature of a given point is what it should be. What the particular temperature is is always a matter of secondary consideration to the workman; in fact, often it is desirable to keep him entirely in ignorance of the true temperature. Pyrometers of the conventional type emphasize first of all the true temperature, though often in disguised units, and the workman, in one way or another, must transpose this and figure how far his temperature is in error.

The Leeds & Northrup Company, of Philadelphia, has recently gotten out literature describing a style of pyrometer which the company has been making that is a striking departure from the conventional lines.

The hardening and annealing pyrometer made by this firm tells the workman first of all, and directly, what it is most important he should know, namely, that the temperature is right, or that it is too high or too low; if high or low, how much too high or too low. "Right" may be varied at will throughout any range below 1800°. The hardening and annealing pyrometer consists of three parts, the bulb, the indicator and the deflector. The bulb, suitably protected, is in the furnace, the workman watches the needle of the deflector and may or may not see the indicator.

The instrument is based on the measurement of temperature by means of the measurement of the change in electrical resistance of pure platinum. There is no cold end to attend. The scale of the deflector, which is, in reality, an ordinary voltmeter with special scale, is divided into 100 divisions; each side of a central zero. When the temperature is fifty degrees too high, the needle stands approximately on the + 50 mark; when it is seventy-five degrees too low, the needle stands approximately at - 75, etc. By turning the index on the indicator, the temperature corresponding to 0 may be varied at will. Thus,

if it was desired to treat a piece of steel at 1380° F., the index would be set at 1380, and the temperature of the furnace raised until the needle stood at the center of the scale. If the next piece was to be heated at 1420° F., the index would be set at 1420, and the needle again brought to the center of the scale. The ordinary thermal couple instrument has crowded on its single six-inch scale its total temperature range from 0 to 2000° F. In a given process with a given kind of iron or steel, at least ninety per cent. of this scale is without use.

On such an instrument $\frac{1}{4}$ " on the scale corresponds to 20° to 50°. On the Leeds & Northrup deflection indicator, $\frac{1}{4}$ " corresponds to 5° approximately. The workman does not have to remember at what temperature he is working. The deflection does not tell him what the temperature of the furnace is; it tells him that the furnace is so many degrees away from the correct temperature. He can at any time, by looking at the index on the box, tell at what temperature the furnace is supposed to be held. Or, should it be desired, this index may be in the superintendent's office or kept from the furnace-man's sight. In any case, the first thing that strikes the furnace-man's eye is that the temperature is higher or lower than it should be, or that it is just right, depending on whether the needle is to the right or the left of the center or just in the center.

When thirty degrees means a deflection half-way off the scale of the pyrometer, even the most careless workman will get busy to correct the error, but when thirty degrees means only a $\frac{1}{16}$ " to $\frac{1}{8}$ " motion, the average man naturally thinks "that little bit won't hurt."

It does not require a deep knowledge of psychology, and especially of the psychology of the American workman, to know that small things do not receive the consideration that big things do. With a workman reading a pyrometer, it is the amount of space covered by the needle which counts; the scale receives scant consideration. An eighth of an inch is to him an eighth of an inch, regardless of whether that eighth of an inch stands for 5° or 50°.

With the average workman the above statement is almost rigidly true; hence, a pyrometer upon whose scale an eighth of an inch equals 5° acts as an unconscious stimulant to the workman.

It is also a fact that with a pyrometer readable to 2° it is very much easier to control temperature within set limits than it is with an instrument readable to only 25°, for the reason that as soon as the source of heat, be it gas, coal, oil or electricity, begins to vary, the change is immediately noticeable and may be immediately remedied. This does not give the furnace conditions a chance to get "a set" which necessitates radical action to correct, such action starting the temperature change in the other direction.

From one point of view, a pyrometer scale resembles the thread on the gate valve of an engine; the greater the motion of the valve handle for a given change in speed, the finer may the speed be regulated; the greater the motion of the pyrometer needle for a given change in temperature, the closer may the temperature be controlled.

The measurement of temperature is in reality a problem in electrical measuring instruments, in which the Leeds & Northrup Company, of Philadelphia, has an enviable reputation.

Aluminium Welding.

With reference to the article by Mr. M. U. Schoop on aluminium welding, printed elsewhere in this issue, the following notes should be of interest as the Schoop system of welding is now being introduced into practice on a large scale in Europe.

While in all other cases of soldering and welding a most careful cleaning of the surface is necessary, this is not required for aluminium welding, if only the surface looks bright.

If sheets of medium thickness are to be welded together, the method of butt welding is employed, or the sheets are made

to overlap, and the Schoop flux paste is applied with the finger or a brush at the place where the joint is to be made. Attention must be paid to the fact that aluminium has a large condition of expansion.² For this reason sufficient space must be left in butt welding, according to the thickness of the sheets. During the welding operation aluminium is dropped on to the joint in form of wire and the like. In the case of thin sheets, it is best to bend the rim of one sheet upwards, and use the up-bent material for the joint.

The greatest difficulties are perhaps found in soldering very thin sheets of aluminium of $\frac{1}{2}$ to $1/10$ mm thickness (20 to 4 mils), such as are used in modern airship construction, for packing tea, cocoa, etc., for oversea transport, etc. With sufficient skill, however, even this problem may be solved. A skilled workman will also be able to make vertical or horizontal joints at will. This may be necessary in making large containers from a number of sheets.

It may finally be mentioned that Count Zeppelin has been using this method of welding aluminium since 1906 in the construction of his airships, and has stated that the joints are proving excellent and that the union is so good that the place of the joints can no longer be noticed.

In this connection it may be interesting to mention another method of aluminium welding, due to Mr. Sherard Cowper-Coles, of London, who has now perfected a compact welding machine. While it is generally recognized that it is the very thin invisible oxide film on the surface which makes aluminium welding so difficult, it is interesting to note that Mr. Cowper-Coles' machine makes use of this obnoxious film in the following ingenious way:

The principle underlying the process is as follows: The ends of the rod to be jointed are butted, after facing square, and heat from a gas blowpipe or benzine lamp is applied at the joint, which rapidly produces an oxide skin, and the fused metal is retained within this skin of oxide. When the ends of the rod are molten they are brought rapidly together by releasing a spring catch. The oxide skin, bursting at the point of contact, is driven out by the pressure of the spring and the clean molten metal united and makes a perfect joint.

Notes.

New York Section American Electrochemical Society.—A well attended and very interesting meeting was held on March 27 at the Chemists' Club in New York City. Dr. Chas. Baskerville was in the chair. Prof. W. D. Bancroft presented two papers, on "The Chemical Electrolysis of Acetates" and on "Electrolytic Production of Aniline." Dr. J. W. Turrentine also presented two papers, on "A Modified Oxy-hydrogen Gas Corlometer" and on "A New Form of Laboratory Apparatus." Mr. Maximilian Toch read a second paper on "The Protection of Steel Against Corrosion," and Mr. C. F. Carrier, Jr., spoke briefly on "Cheap Power from Steam" in connection with a sodium chloride electrolysis scheme, the exhaust steam being used for evaporation.

Wisconsin Section American Electrochemical Society.—At a meeting held on April 5 in the lecture room of the Chemical Engineering Building of the University of Wisconsin, at Madison, Mr. Carl Hambuechen lectured on "The Manufacture of Dry Batteries." The attendance was 50.

Engineering Society of Wisconsin.—The engineers of Wisconsin have formed a State society with over 150 charter members. The first meeting was held at the University of Wisconsin from April 24 to 26. Among the papers presented was one by Prof. C. F. Burgess, who discussed the new prob-

lem of standard of gas and electric service. Professor Burgess has done important work in enabling the Wisconsin State Railroad Commission to prescribe a standard for fuel and illuminating gas.

Gauges.—The Bristol Company, of Waterbury, Conn., have issued an illustrated bulletin on their recording gauges for pressure and vacuum, and are about to issue a more extensive catalog on the same subject.

Swenson Evaporator.—The name of the corporation manufacturing the Swenson evaporator, leaching cells, diffusion batteries, heaters and other chemical machinery, has been changed from the American Foundry & Machinery Company to the Swenson Evaporator Company. The office will be as before, at 944-5-6 Monadnock Block, Chicago. The new company have retained the same organization and Mr. F. M. de Beers, formerly manager of the American Foundry & Machinery Company, will continue in charge of the business.

Museum of Safety and Sanitation.—The executive committee of the Museum of Safety and Sanitation, 29 West Thirty-ninth Street, New York City, has detailed Dr. Wm. H. Tolman, the director, for field work. He will start on May 1 on a lecturing tour. Chambers of commerce, manufacturers' associations, engineering, insurance and architectural societies, railway and other clubs, may avail themselves of this illustrated exposition of devices and methods for the cost of the lantern operator (\$10), if not too far removed from the itinerary.

Digest of U. S. Patents

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

ELECTRIC FURNACES (Continued).

No. 589,048, Aug. 31, 1897. Charles A. Timme, of New York City, N. Y.

Resistance type. This furnace is a rectangular muffle for dental use, capable of heating articles to a temperature of 3500 F. The muffle is a box of metal with a non-conducting lining, within which are removable heating-plates, formed of refractory material with an imbedded platinum resistance wire. The top and bottom plates slide on flanges. The temperature in the muffle may be varied by switching in one or more plates, or a portion only of one plate. The front of the muffle is closed by a cover having a peep-hole.

No. 597,476, Jan. 18, 1898, Thomas L. Willson, of New York City, N. Y.

Arc type. This furnace, especially designed for the production of calcium carbide, is a brick-work structure containing two smelting chambers. Each chamber may receive a cast-iron pot on wheels, serving as the lower electrode; or the chamber may have a fixed hearth consisting of a horizontal iron plate, and side walls of carbon. The upper electrode is a depending carbon block consisting of a number of plates, the upper ends of which are held in a metal clamp carried by an adjustable stem. This stem is square and passes through a square opening in the adjacent edges of hinged trap-doors above. Hoppers deliver the charge-mixture through ports into the smelting chamber at each side of the depending electrode. The iron pots have a horizontal rib at one side, which is gripped by a number of iron clamps individually connected to one set of electric conductors. The other set of flexible conductors is connected to several horizontal rods projecting from the stem of the upper electrode. The calcium carbide gradually builds up in the bottom of the pot until it is filled. The pot is then wheeled out and replaced by an empty one, the carbide in the filled one being cooled and dumped. Or the molten material may be tapped from the crucible or fixed hearth. Or the material may be allowed to solidify on the fixed hearth, the door opened, the loose material poked away and the pig of carbide pulled out by hooks. The fumes from the chamber pass

*These are comparative figures for aluminium and copper:

	Aluminium.	Copper.
Density	2.68	8.93
Specific resistance	2.88×10^{-6}	1.8×10^{-6}
Tensile strength in kilograms per square millimeter	20.0	30.0
Linear coefficient of expansion	0.231×10^{-4}	0.18×10^{-4}

through a settling-chamber containing a series of pockets, and thence escape to a stack.

No. 597,880, Jan. 25, 1898, William Smith Horry, of Sault Ste. Marie, Mich.

Arc type. This furnace, especially designed for the production of calcium carbide, comprises a rotating receptacle in a form of a wheel or annular trough mounted on a horizontal shaft. Carbon electrodes of opposite polarity are adjustably supported on the inclined walls of the feed-hopper opening into the annular trough at one side. The adjacent ends of the carbons are beveled to provide a vertical passage, between which the arc strikes, the charge being fed through it. As the wheel gradually rotates downward from the electrodes, the calcium carbide builds up and plates are bolted onto the trough to retain the carbide and unreduced materials surrounding it. The solidified carbide is removed from the back of the wheel, on the side opposite the electrodes, plates being successively removed from the trough at this point and portions of the carbide pig being broken off. The production of carbide is thus continuous, and the pig is of uniform quality throughout, whereas the carbide produced in non-continuous pot furnaces is poor at the bottom of the pig, rich in the middle, and again poor at the top. The old furnaces also waste much of the charge, the coke and the lime being caked together, but not smelted. The feed-hopper is lined with fire-clay and fire-brick and is pivoted to hang between the flanged sides of the trough. The wheel is slowly rotated by worm and pinion. The rate of rotation is controlled by the operator to maintain the electric current constant.

NEW BOOKS.

THE MINER'S POCKETBOOK. By C. G. Warnford Lock. A reference book for engineers and others engaged in metalliferous mining. Fifth edition, entirely rewritten. 233 illustrations. 632 pages. Bound in leather. Price, \$4 net. New York: Spon & Chamberlain.

THE GAS ENGINE. By Cecil Percy Poole. 100 pages. Bound in cloth. Price, \$1 net. New York: Hill Publishing Company.

SUCTION GAS PLANTS. By C. Alfred Smith. 55 illustrations. 7 + 198 pages. Bound in cloth. Price, \$1.75 net. Philadelphia: Lippincott Company.

WORKING HINTS FOR SUCTION-GAS PRODUCERS. By A. Flurchein. 2 plates. 40 pages. 50 cents net. New York: Spon & Chamberlain.

AN INTRODUCTION TO THE SCIENCE OF RADIOACTIVITY. By C. W. Rafferty. 12 + 208 pages. Bound in cloth. Price, \$1.25 net. New York: Longmans, Green & Company.

A HANDBOOK OF ELECTRICAL TESTING. By H. R. Kempe. Seventh edition. Revised and enlarged. 385 illustrations. 714 pages. Bound in cloth. Price, \$6. New York: Spon & Chamberlain.

ALTERNATING CURRENTS SIMPLY EXPLAINED. By Alfred W. Marshall. An elementary handbook on alternating-current generators, transformers and motors. 90 pages. Paper binding. Price, 25 cents. New York: Spon & Chamberlain.

AN ELECTRIC FURNACE FOR SPECTROSCOPIC INVESTIGATIONS WITH RESULTS FOR THE SPECTRA OF TITANIUM AND VANADIUM. By Arthur Scott King., Washington, D. C. Carnegie Institution of Washington, 1908 (1909). 15 pages. (Contributions from the Mt. Wilson Solar Observatory.)

HEAT FOR ENGINEERS. By C. R. Darling. A treatise on heat, with special regard to its practical applications. 442 pages. Bound in cloth. Price, \$5. New York: Spon & Chamberlain.

Reinforced concrete field handbook. By the editors of *Concrete Engineering*. Allen Brett, Ed. 127 pages. Bound in cloth. Price, \$1. Cleveland: Technical Publishing Company.

MACHINE DRAWING AND DESIGN FOR BEGINNERS. An introductory work for the use of technical students. By H. J.

Spooner. 266 pages. Bound in cloth. Price, \$1.25. New York: Longmans, Green & Company.

LAW AND BUSINESS OF ENGINEERING AND CONTRACTING. By C. Evan Fowler. With numerous forms and blanks for practical use. 9 + 162 pages. Bound in cloth. Price, \$1. New York: McGraw Publishing Company.

BOOK REVIEWS.

Some Electrochemical Centers. A Report to the Electors of the Gartside Scholarship. By J. N. Pring, M.Sc., Gartside Scholar; 138 pages. Retail price in New York, \$1. Manchester: University Press.

It is a pleasure to call attention to this book. It is simply a report on electrochemical industries as they are or were a year or two ago. No attempt is made to discuss hypothetical questions of a scientific nature. But the discussion of the industrial problems is made from a broad viewpoint, both the technical and the economic sides being considered.

There are eleven chapters—short monographs on the following subjects: Cost of power production; Niagara Falls; the copper refineries of New Jersey; Canadian water power and electrochemical centers (including an account of the Betts process); electric smelting of iron ores and steel production; ozone and water purification; gold and silver refining; electrical manufacture of carbon bisulphide; electrochemical industries in the Alps, France and Belgium; the electrical fixation of atmospheric nitrogen; power centers and electrochemical works in Great Britain.

The report of the author is based on information acquired during visits to the United States, Canada and Continental Europe during 1907 and 1908. The author has evidently shown excellent judgment in collecting his information.

This is what the author says on the rapid strides made by the electrochemical industry in America: "Untrammelled by the existence at home of chemical works on a sufficiently extensive scale to provide the rapidly growing demands, the newer processes have here found a very suitable locality for their development, and during their infancy enjoy the fostering influence of a protective tariff. The progress in America is also due in no small measure to the great enterprise and superior technical training of the people."

A comprehensive handbook on industrial electrochemistry remains still to be written. The time is hardly yet ripe for that. But the reviewer says unhesitatingly that this Gartside report of Mr. Pring—though naturally somewhat sketchy in character—is the best all-around book on industrial electrochemistry that has so far come to his notice.

The Design and Equipment of Small Chemical Laboratories. By Richard K. Meade, B. S. 138 pages, illustrated. Price, \$2. Chicago, Ill.: The Chemical Engineer Publishing Company.

This little book is written primarily for young chemists just out of the technical school or college, who have to design a chemical laboratory. The author states that this "often happens." Frankly, we should say that it happens only in a minority of cases.

The book has a wider scope, however, and cannot fail to be useful to the chemist of wider experience, for it contains much useful information and practical hints in a condensed form. In fact, the book could well be enlarged to suit the needs of the research chemist as well as the analytical chemist.

There are 14 chapters dealing with the following subjects: General arrangement; hoods; sinks and water supply; desks; table and apparatus for rapid filtration, etc.; ignition table and apparatus for ignitions; table and apparatus for filtrations; balance support, balance and accessories; heating appliances; preparation of distilled water; apparatus for electrochemical analysis; sampling appliances; assay furnace and accessories; miscellaneous laboratory equipment.